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ALUMINIUM INDUSTRY SUPPLEMENT: WORLD REVIEW OF PROGRESS.

METALLURGIA

THE BRITISH JOURNAL OF METALS

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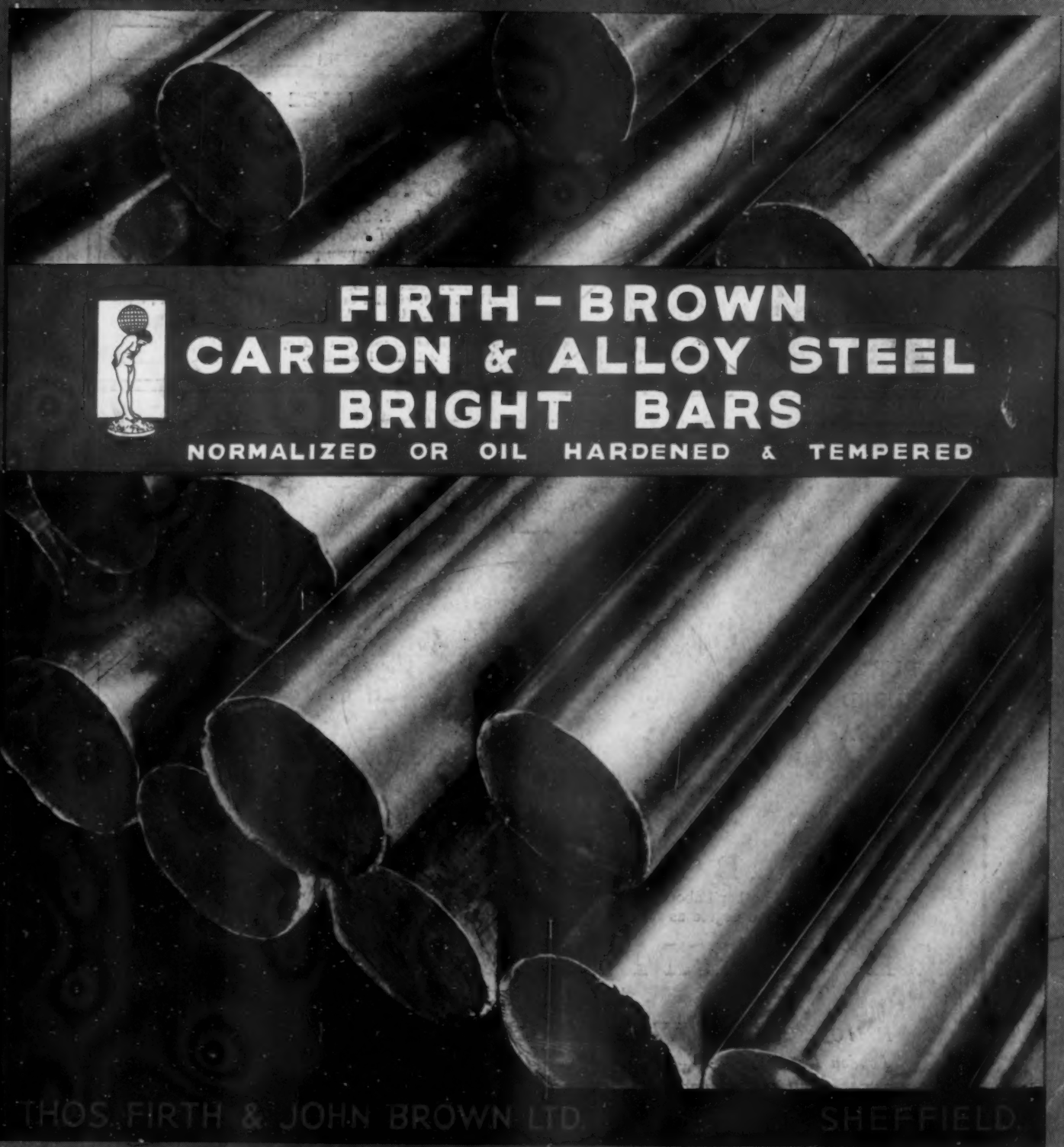

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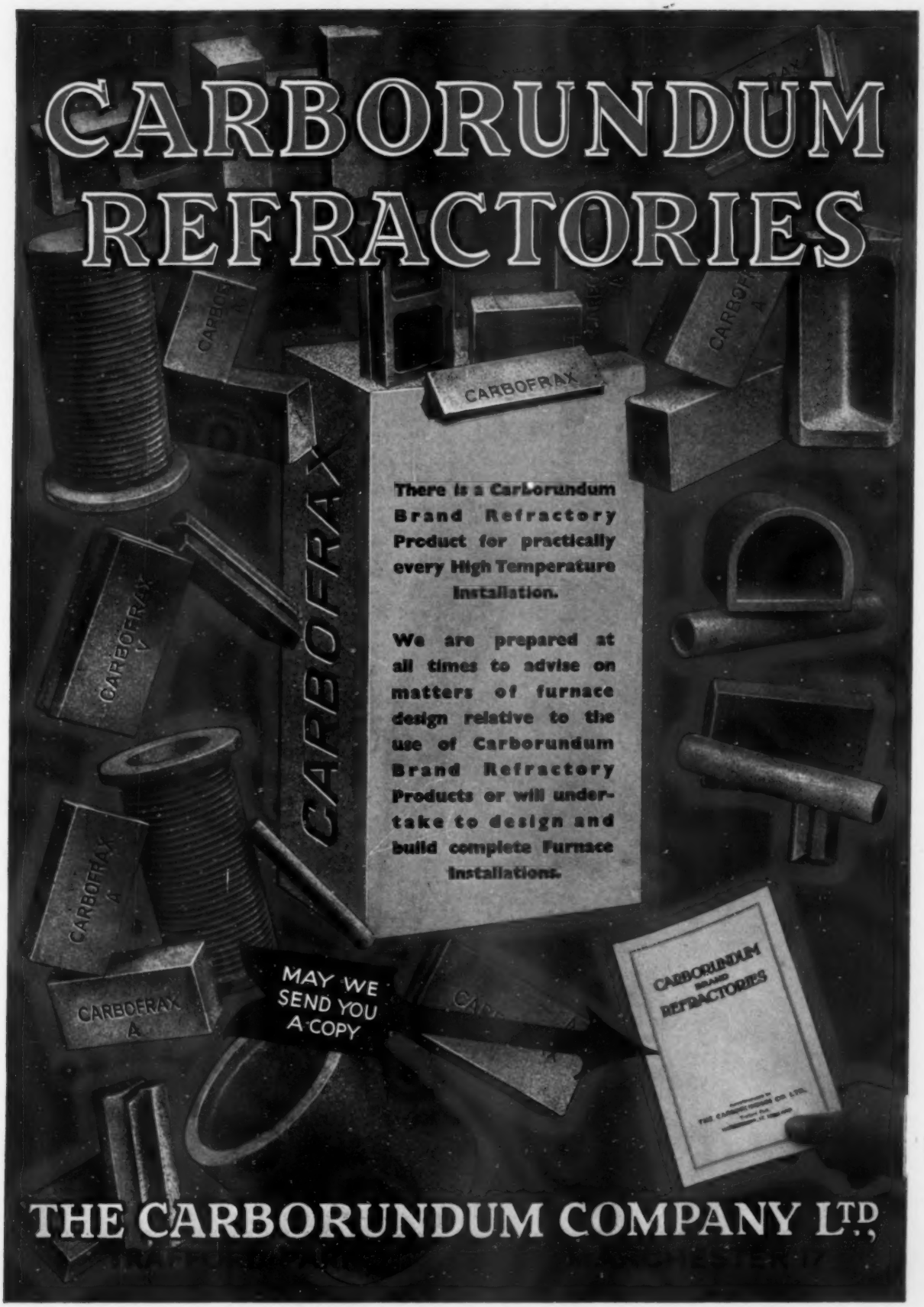
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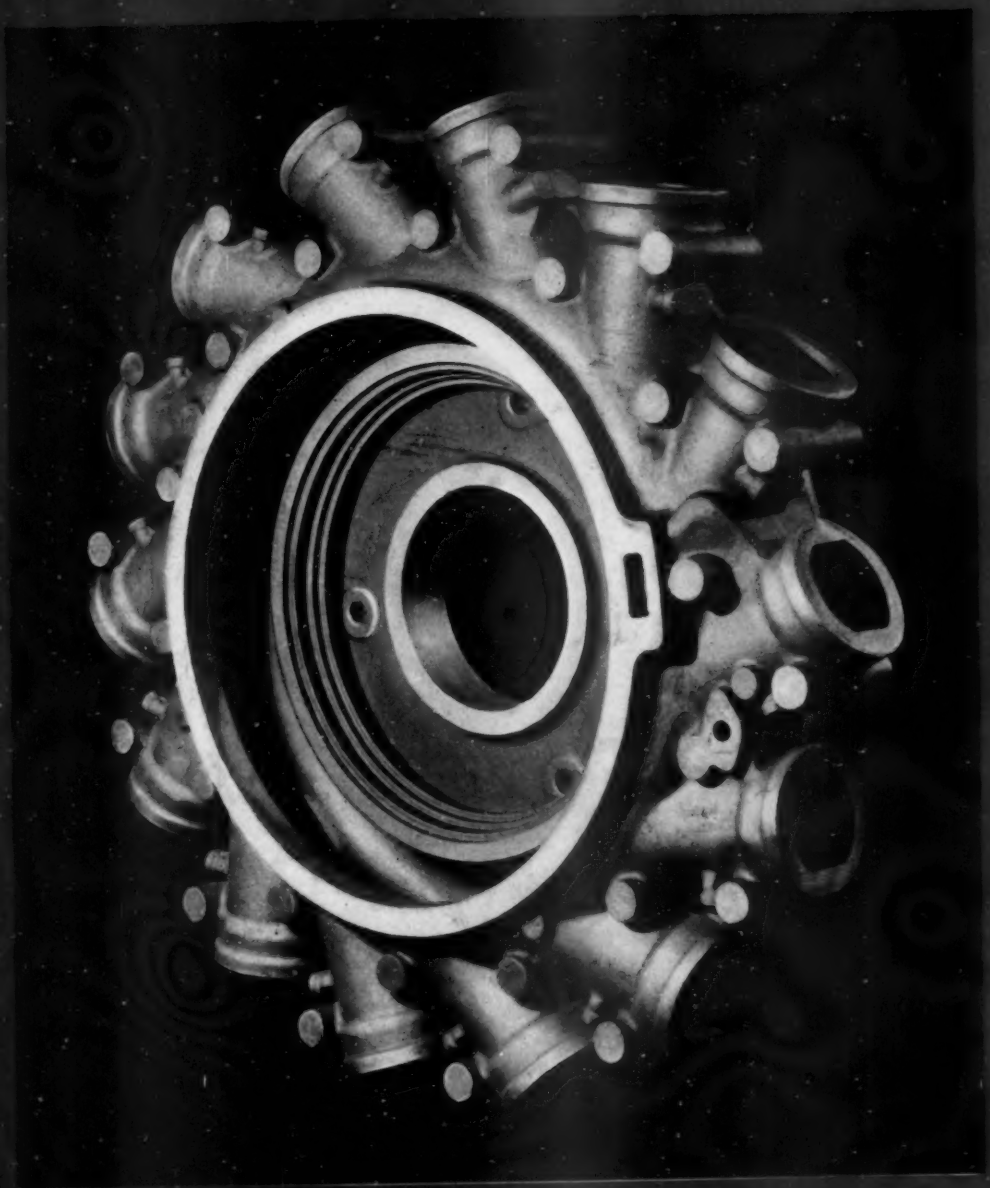

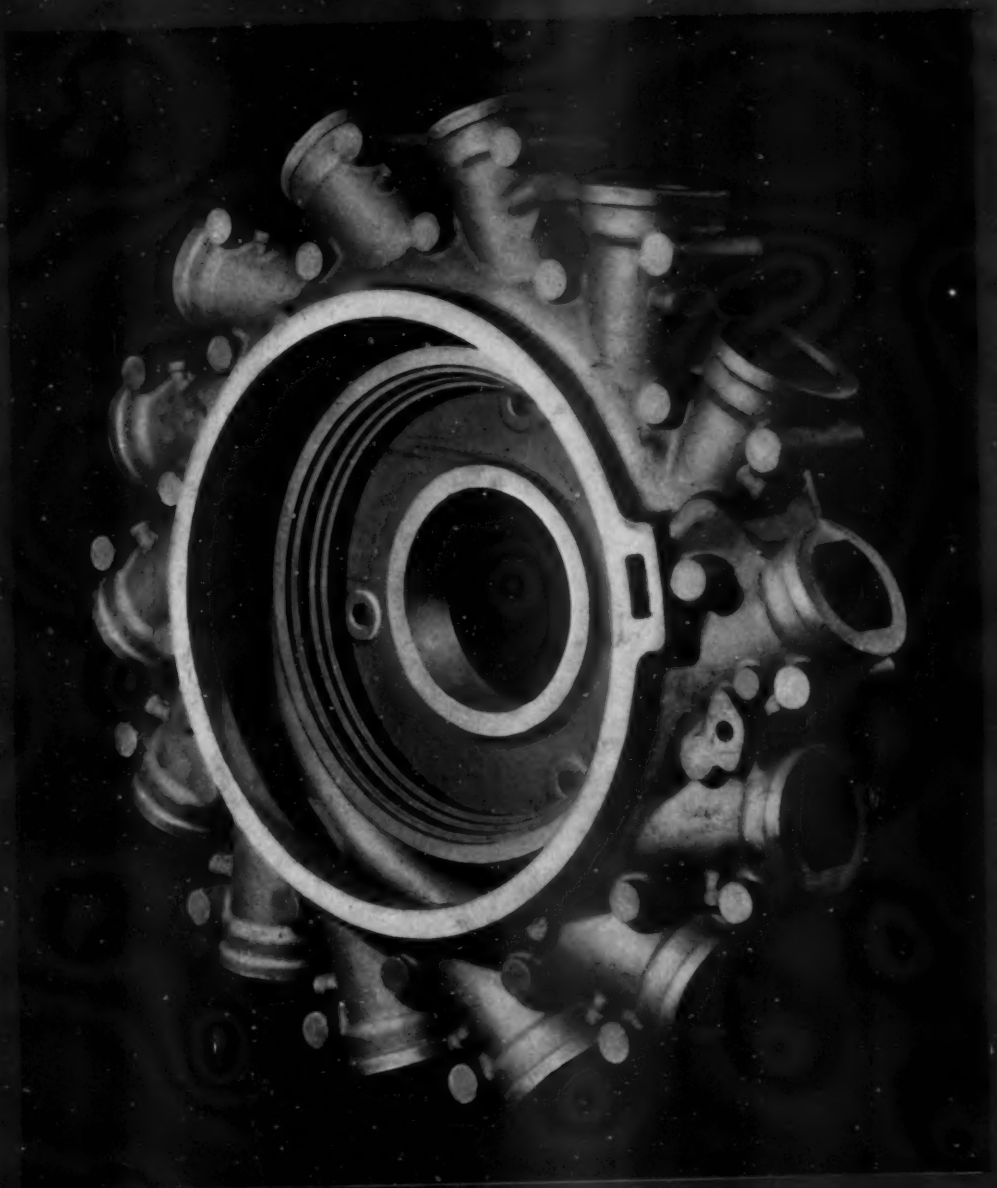

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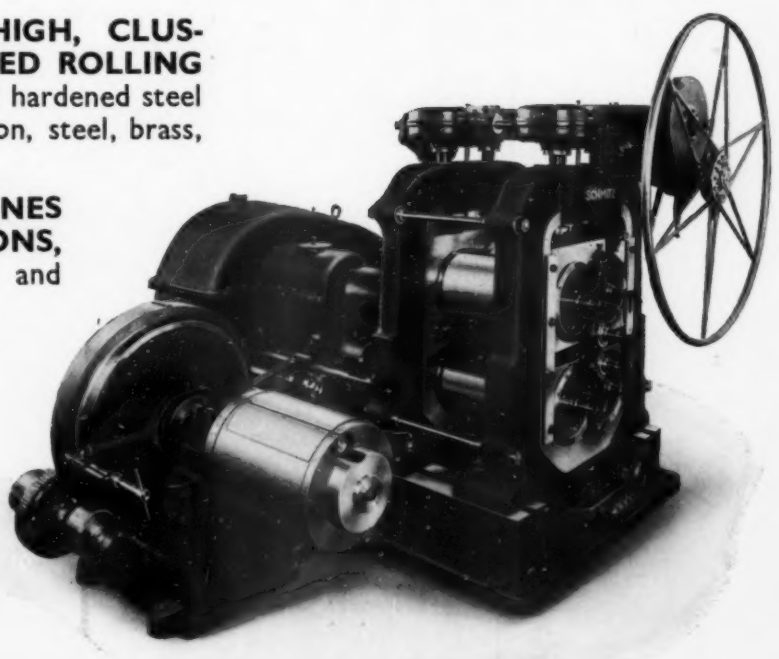

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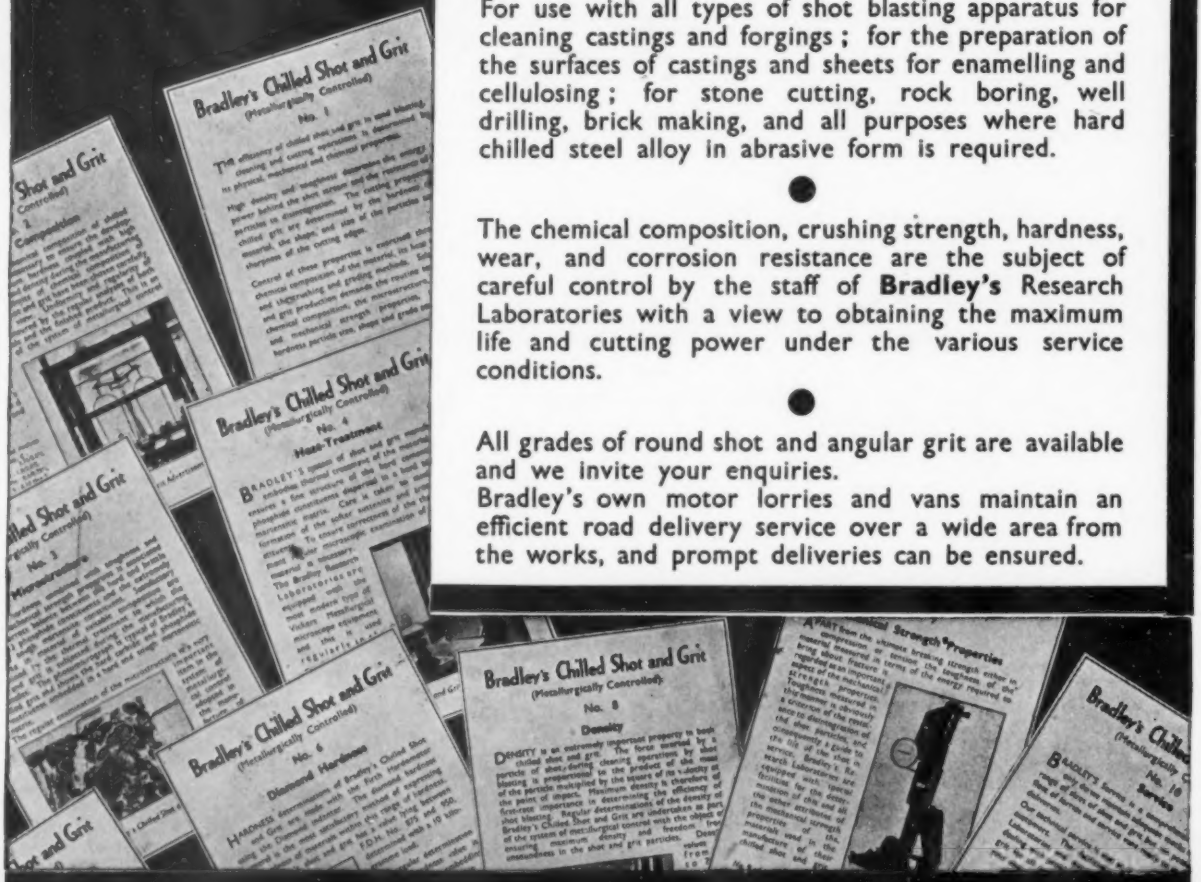

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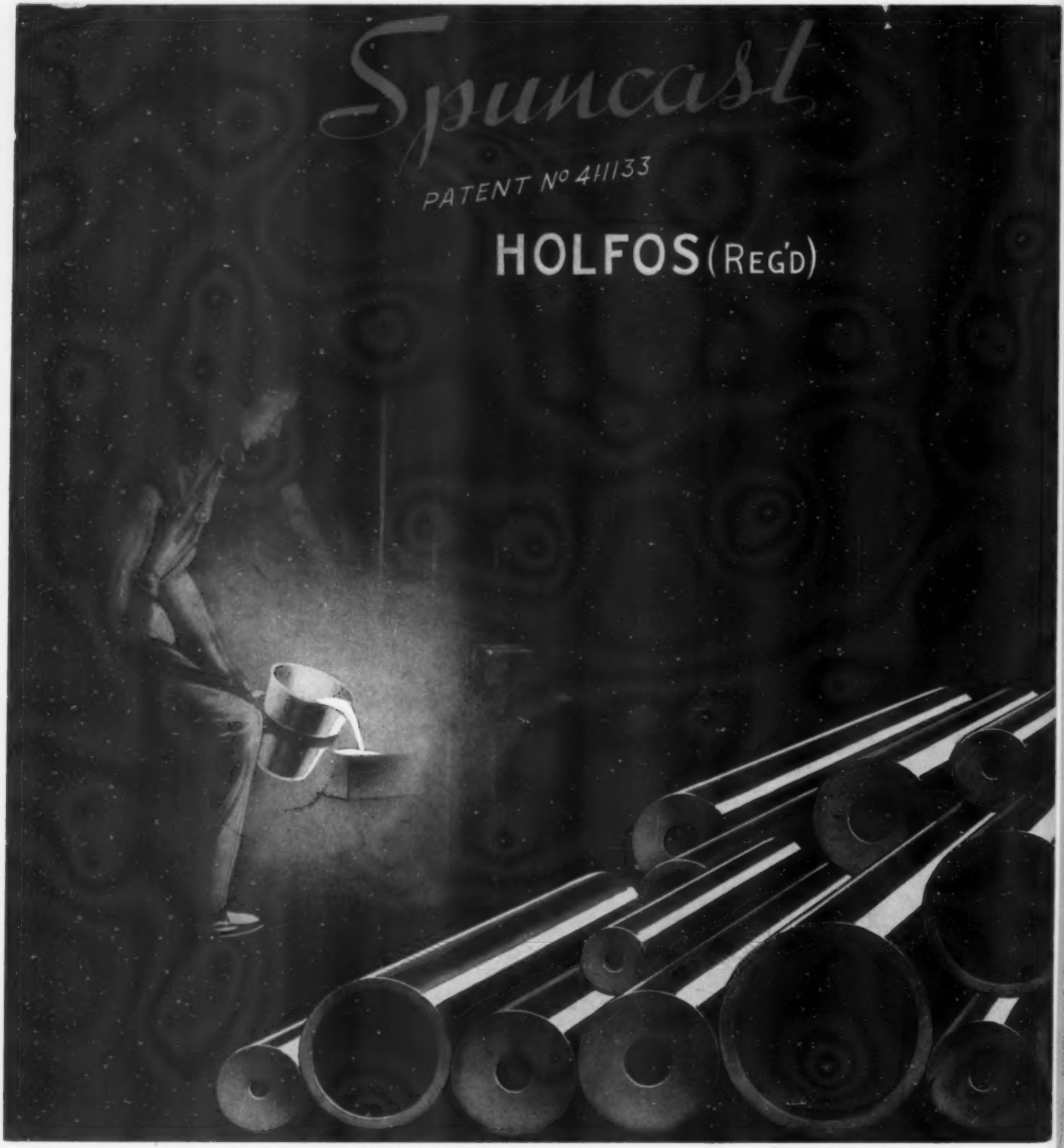

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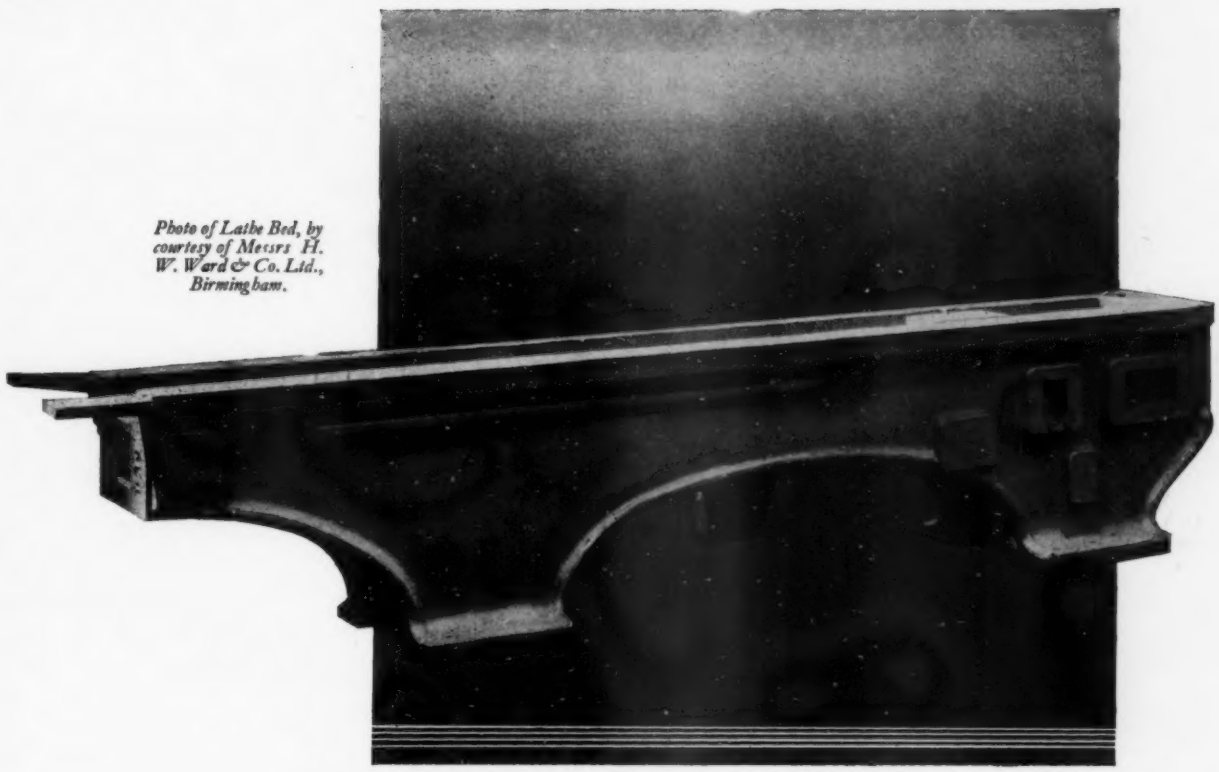

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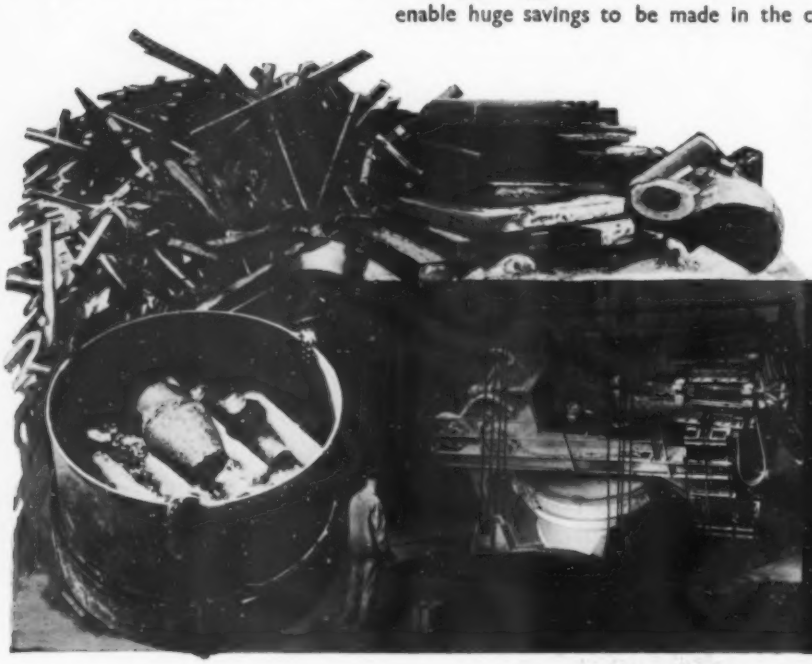

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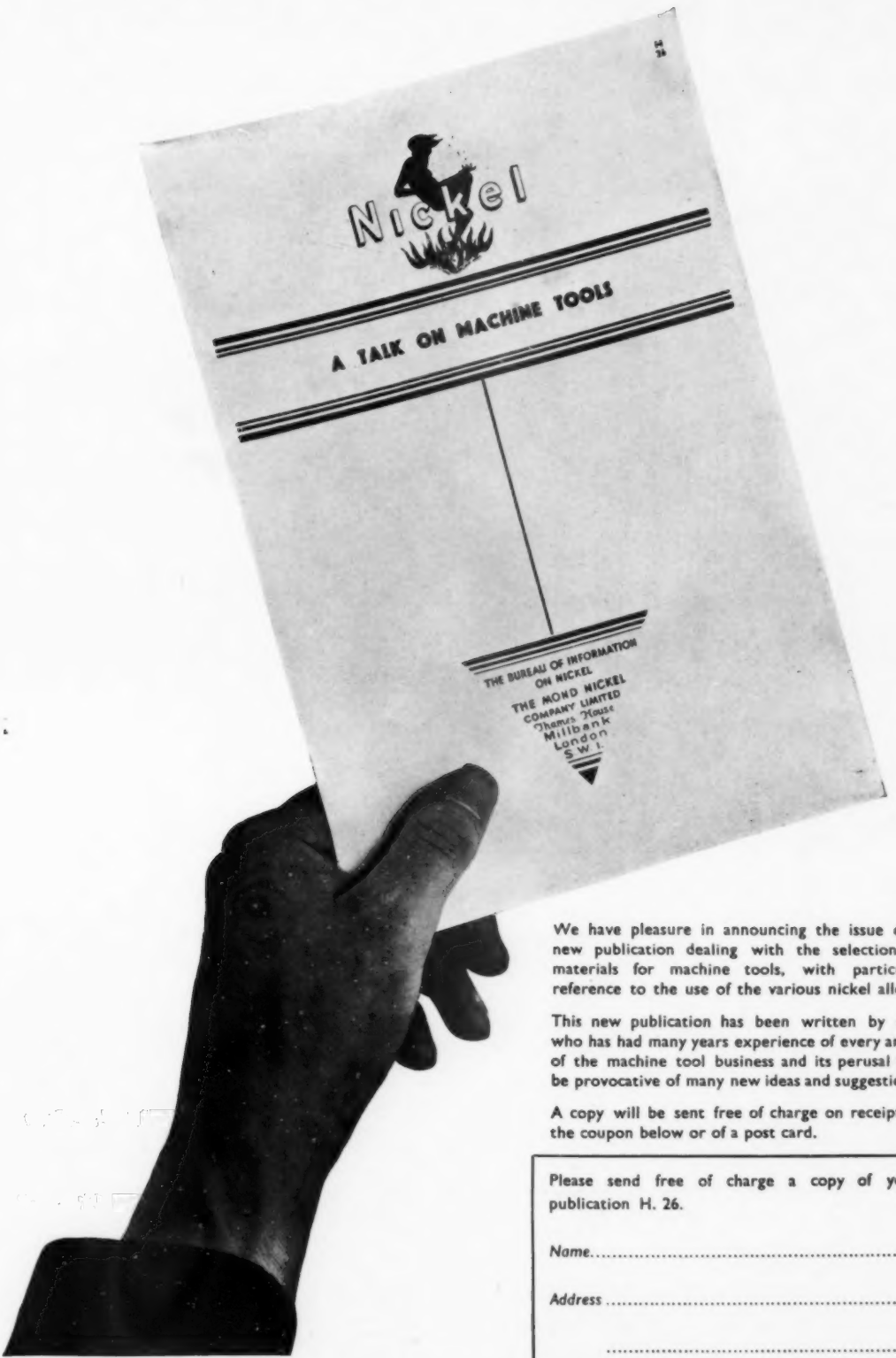

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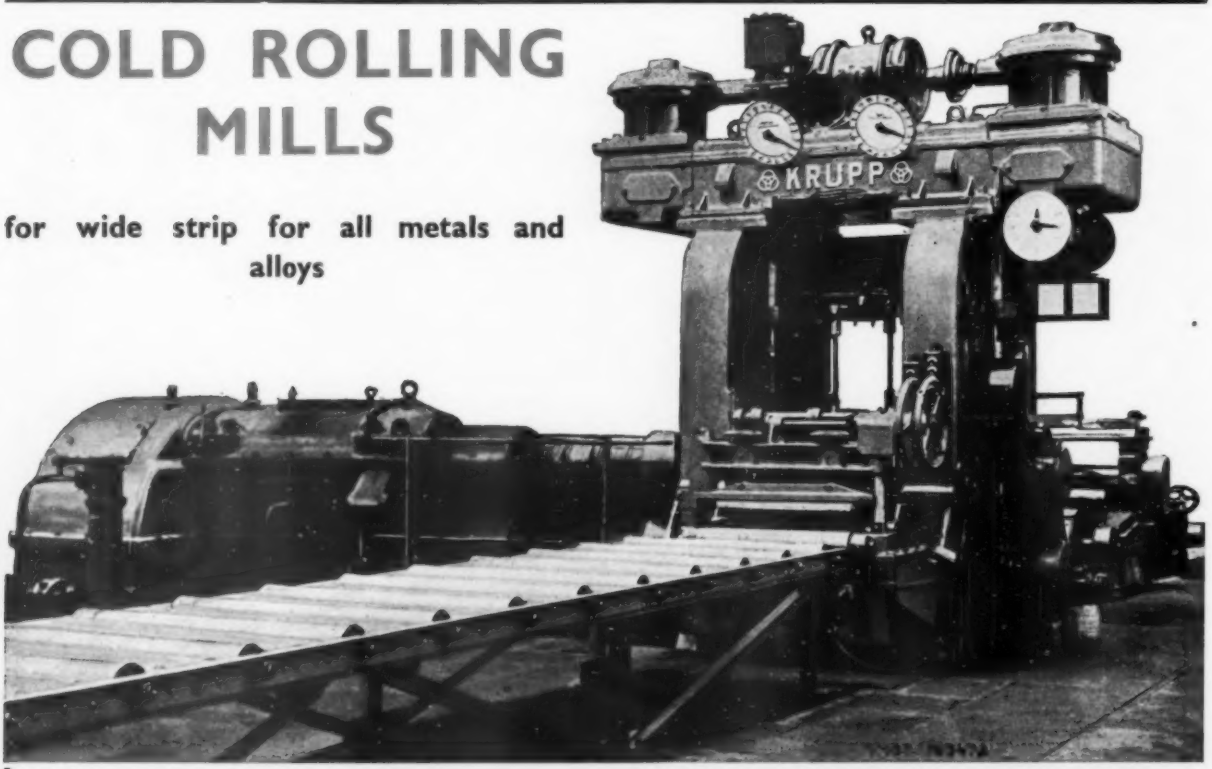

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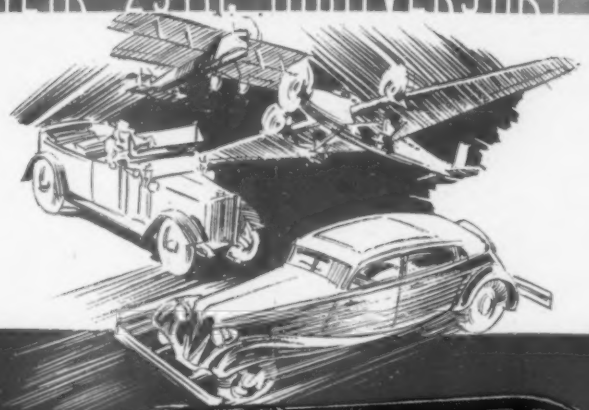

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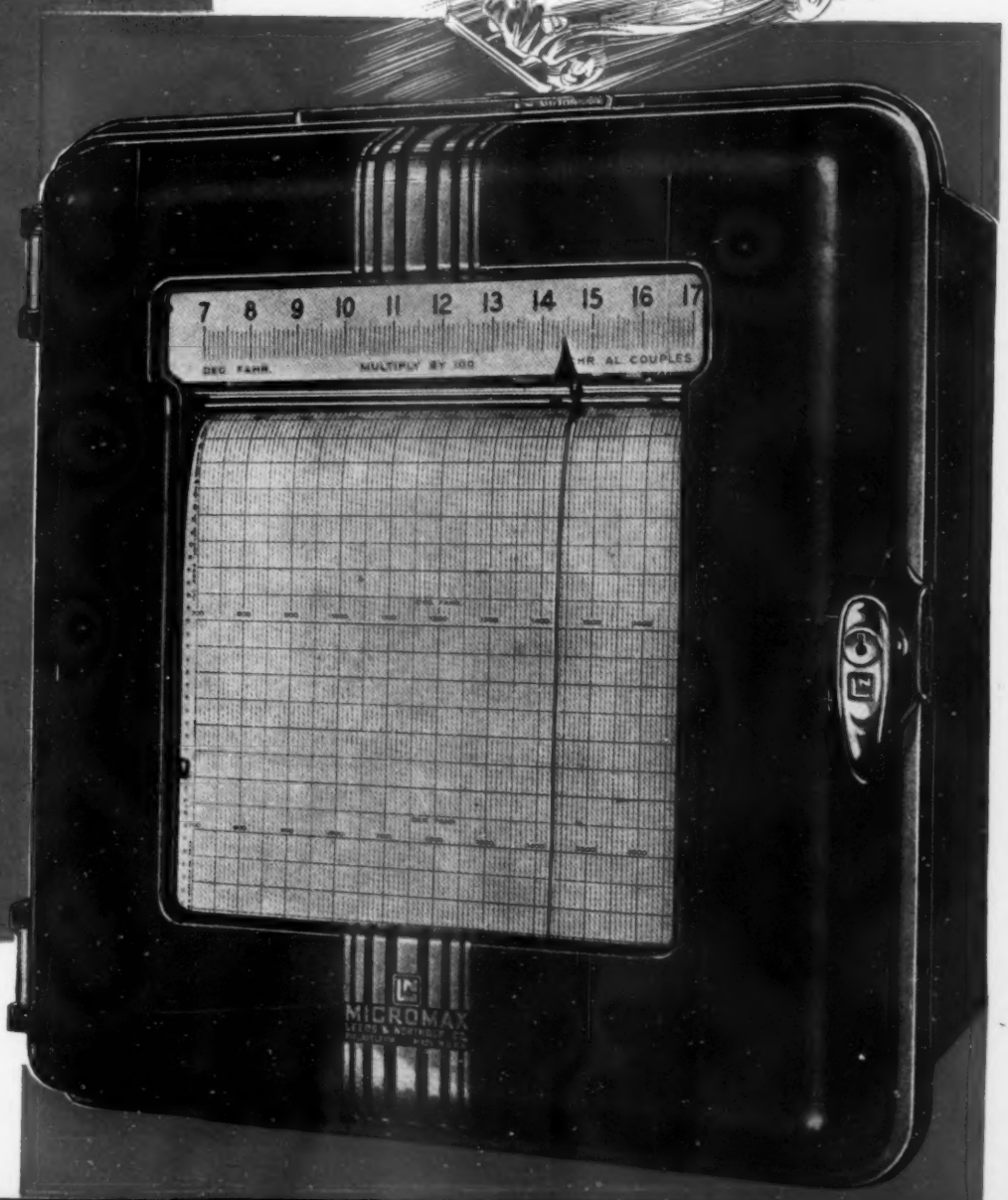

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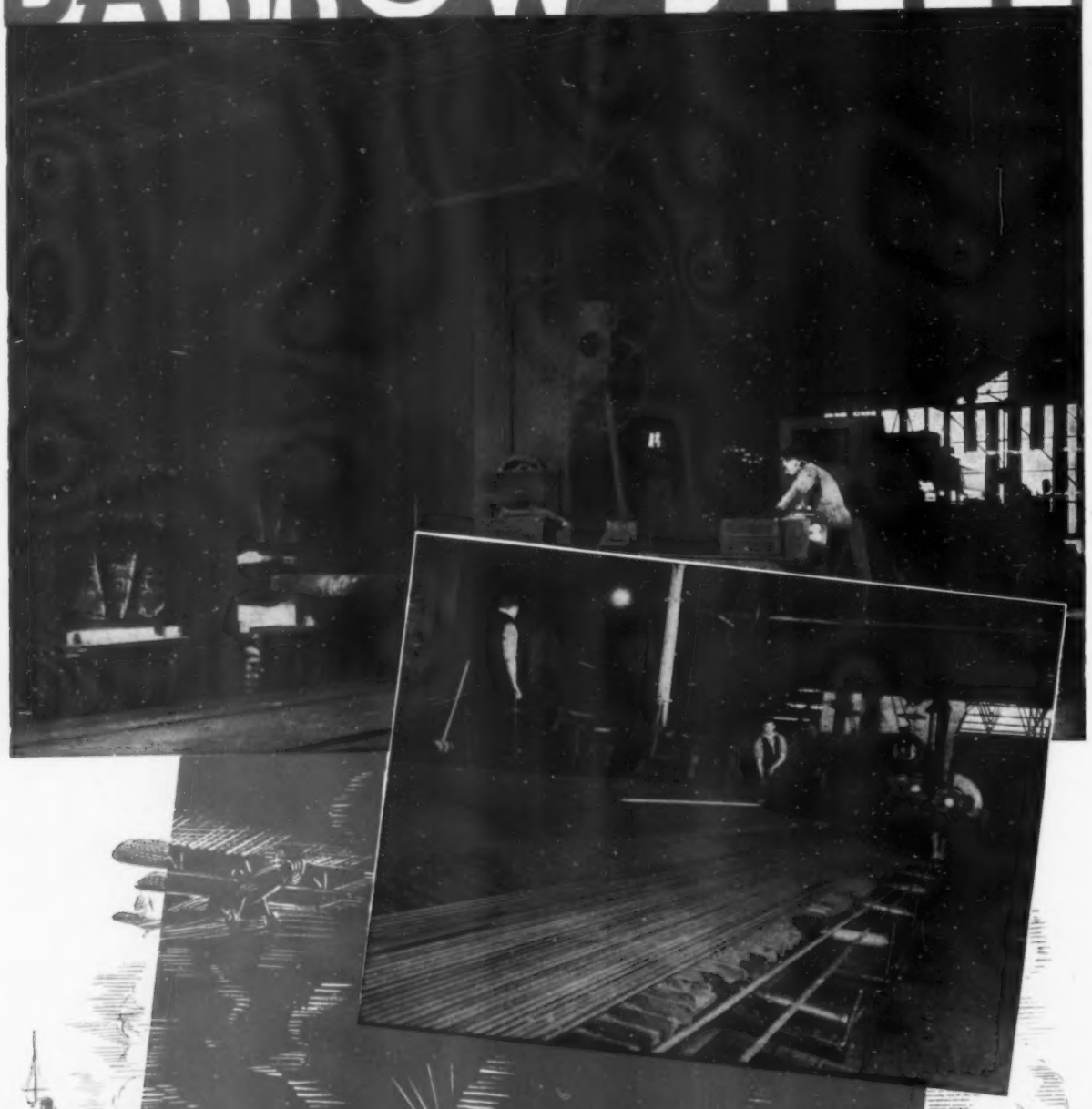

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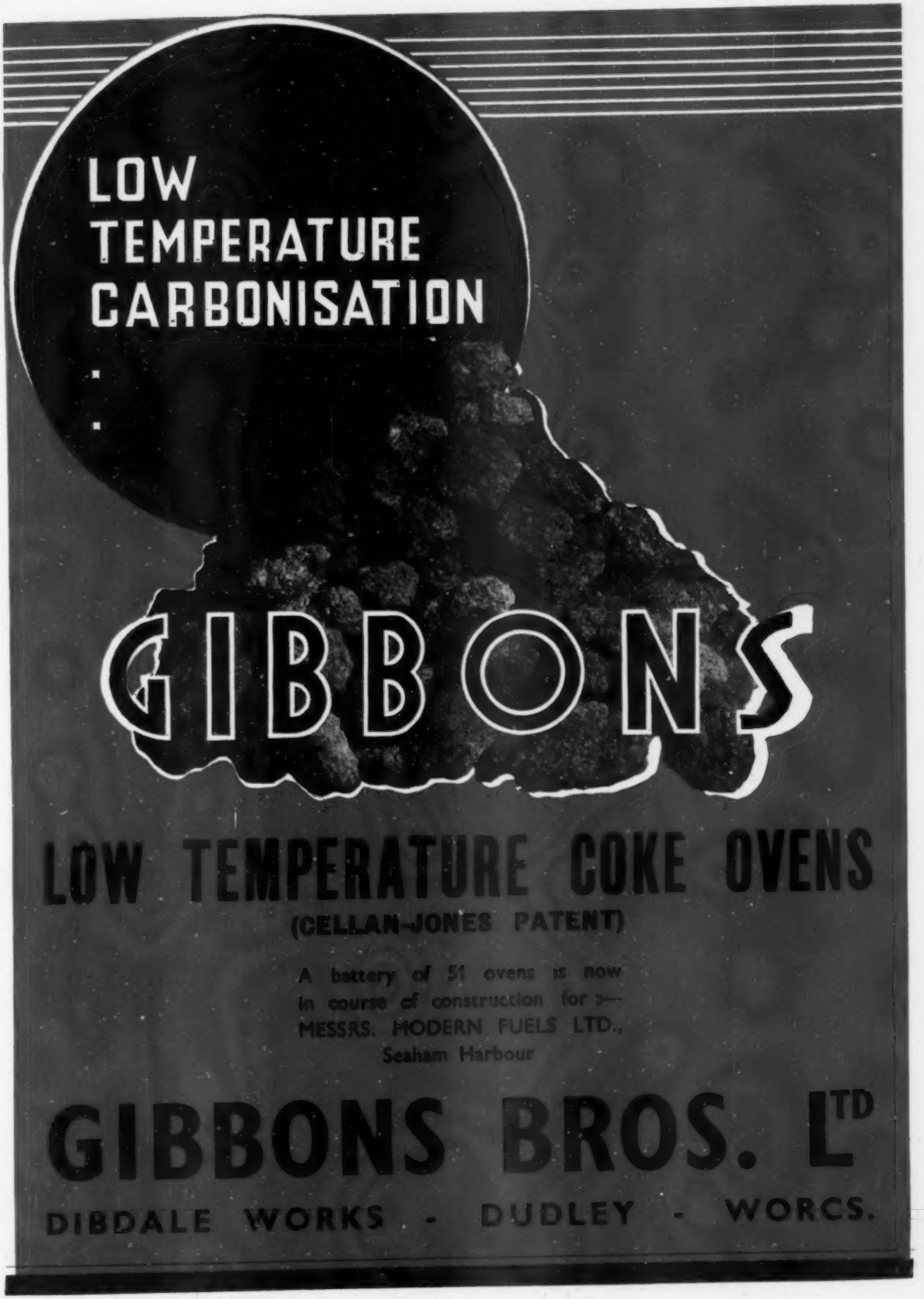
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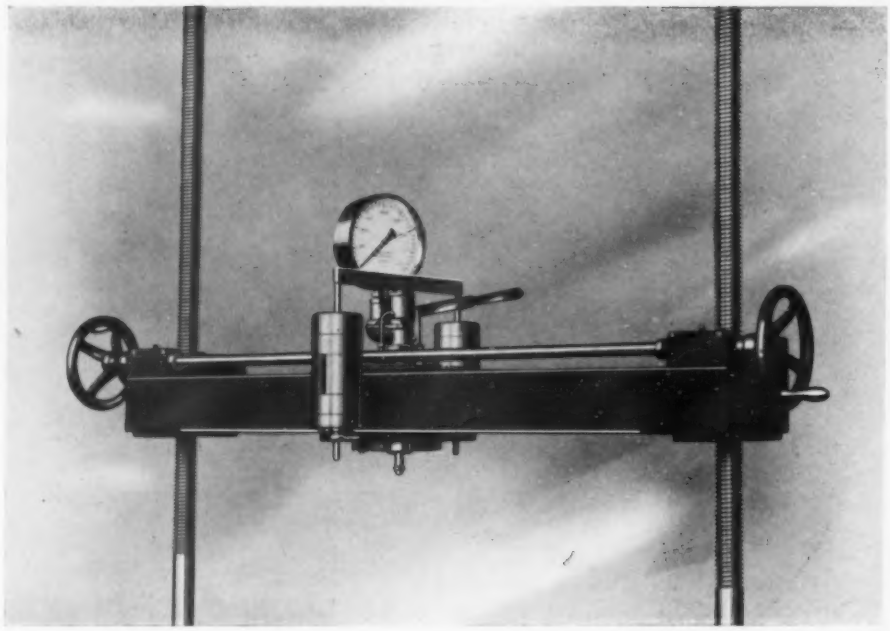

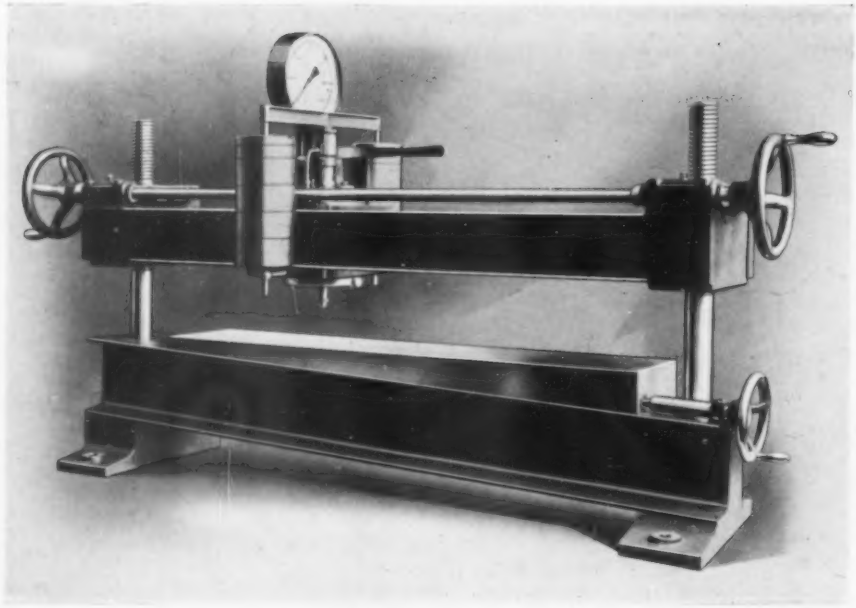

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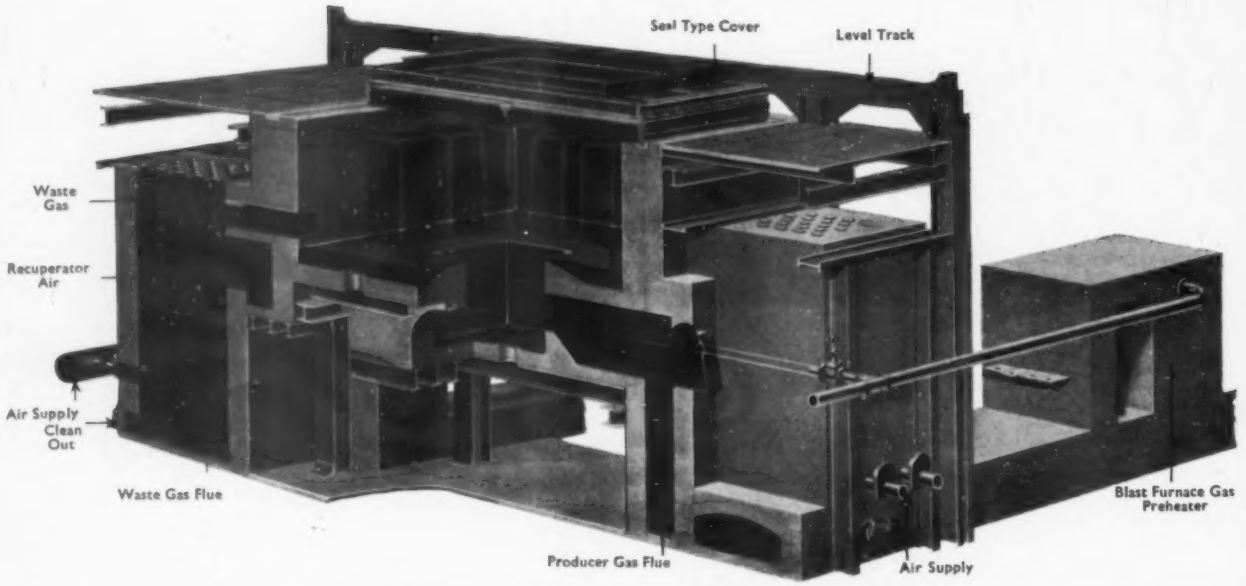

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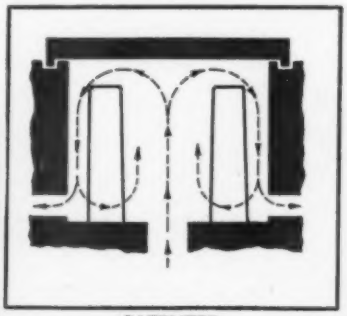

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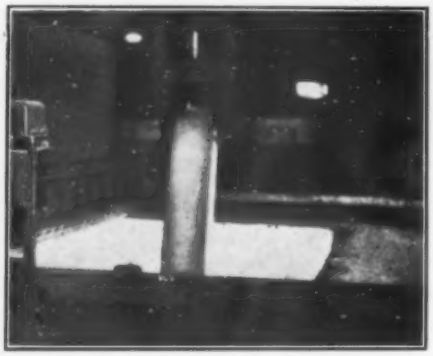

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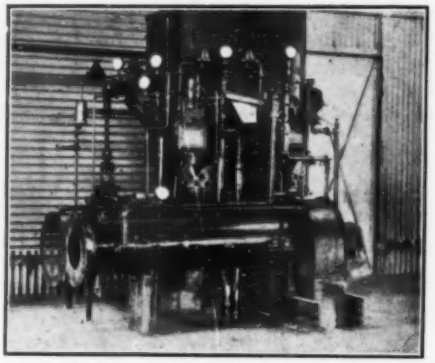

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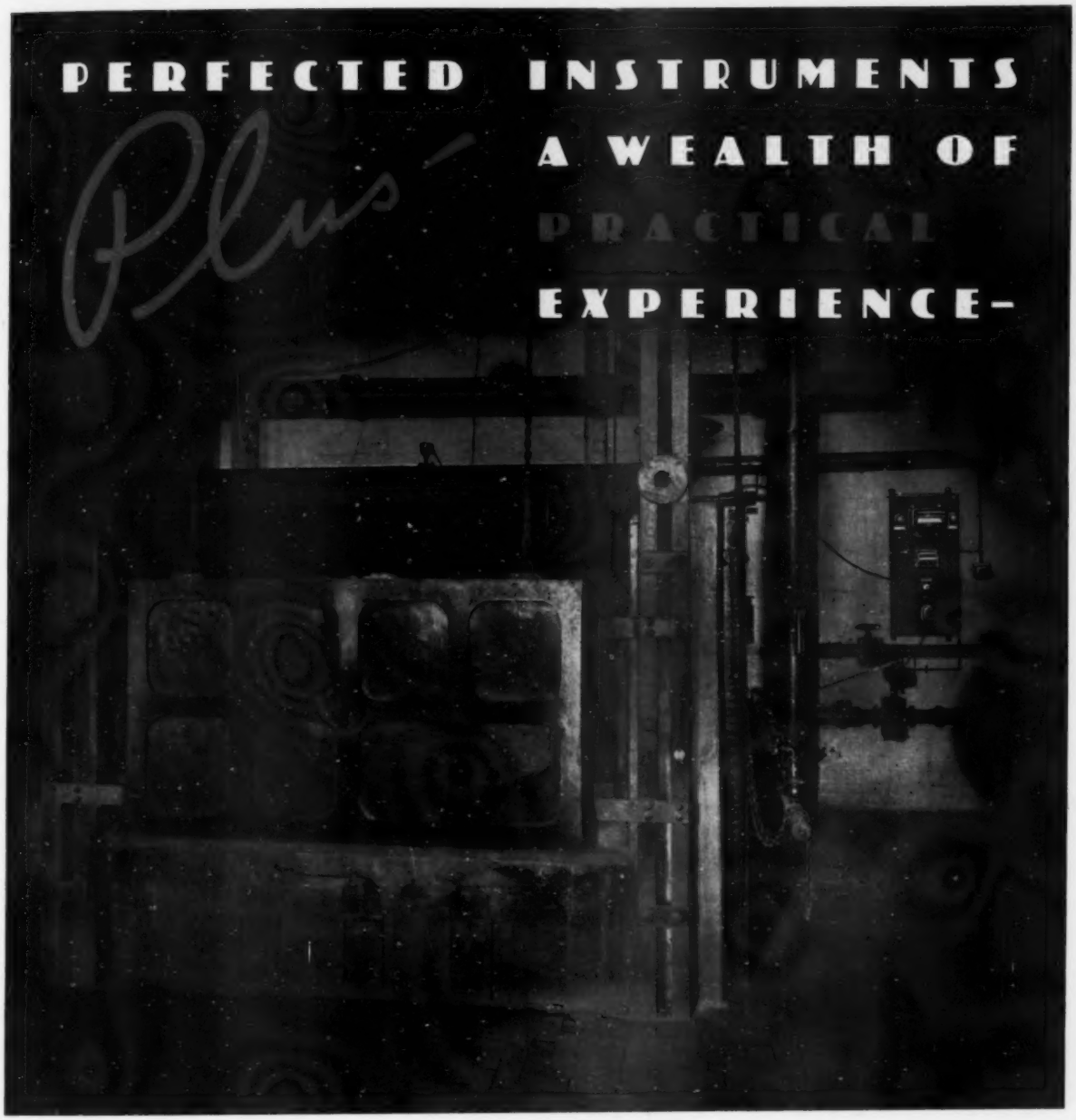

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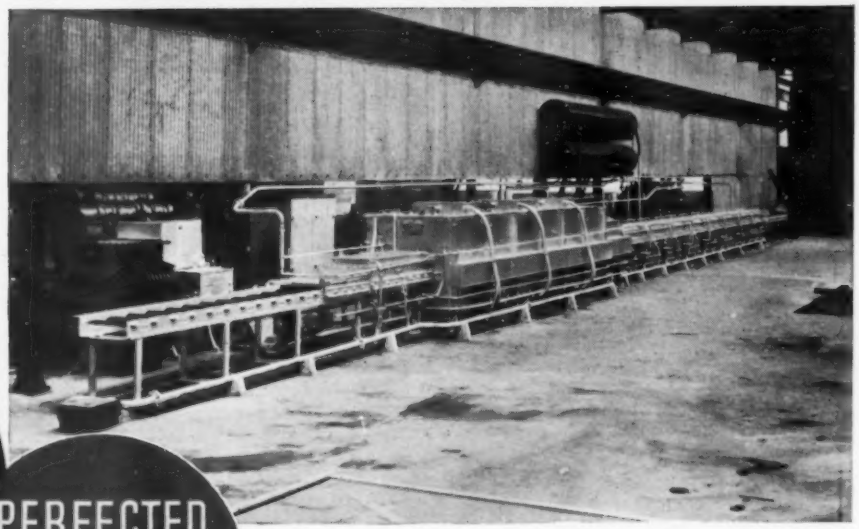

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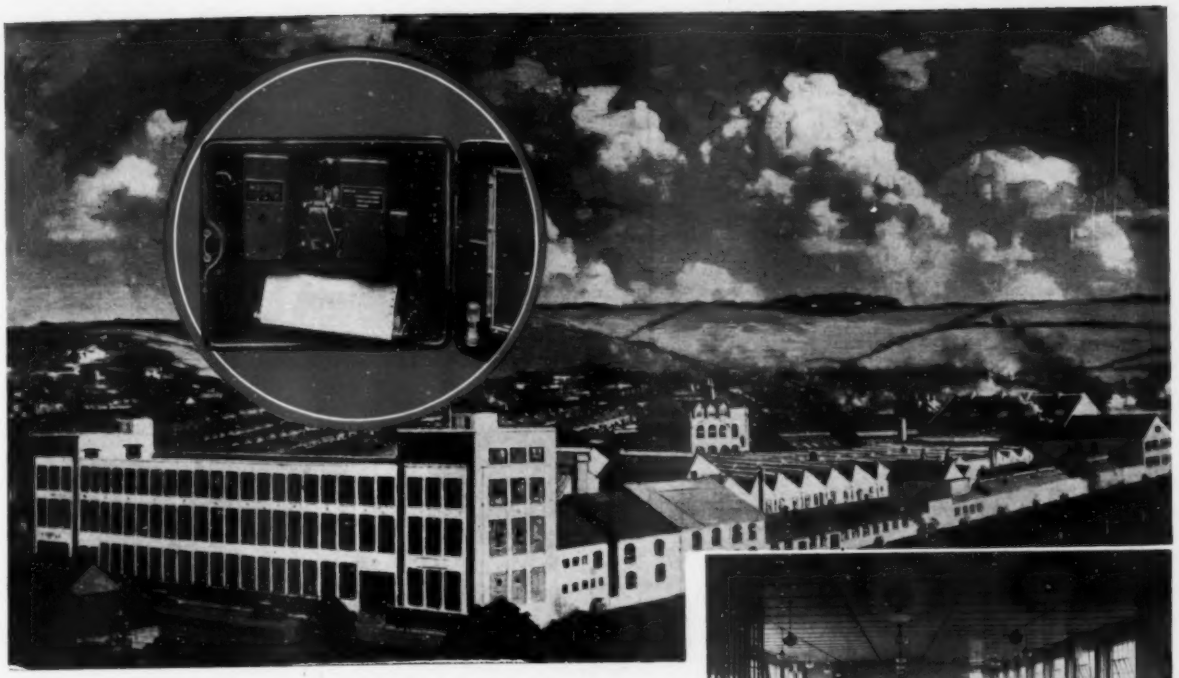

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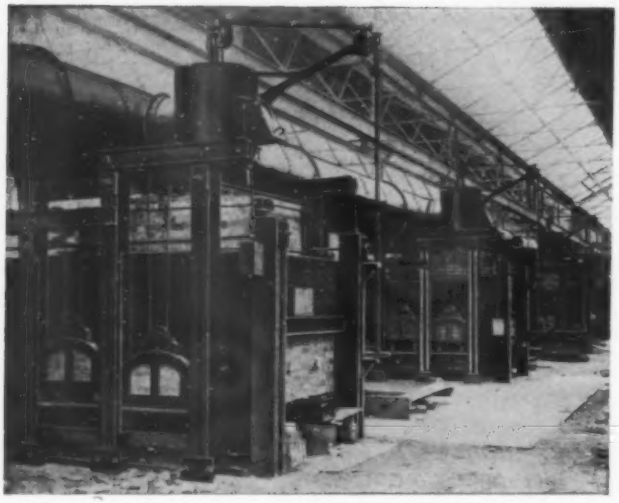

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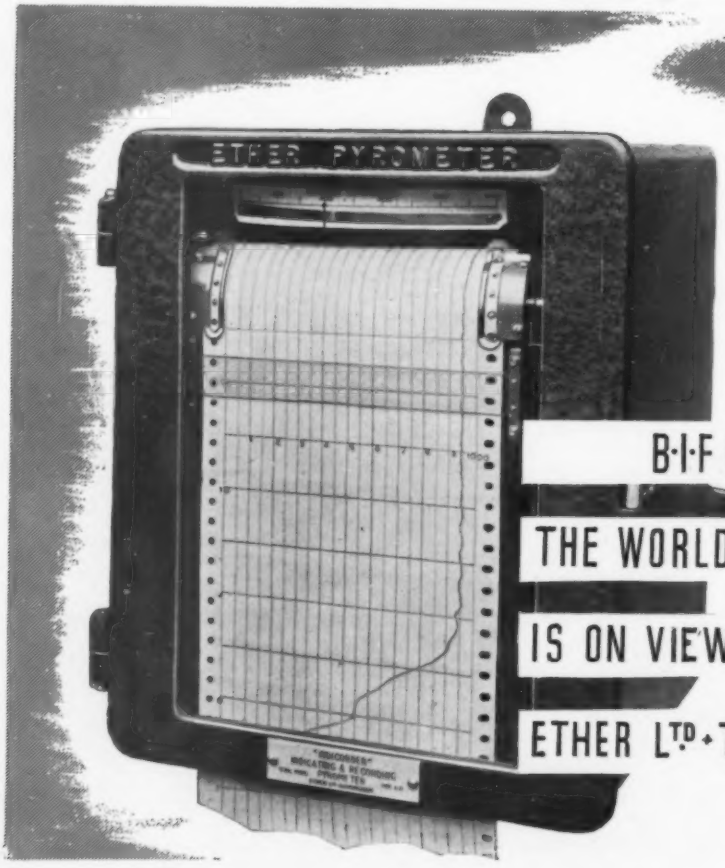

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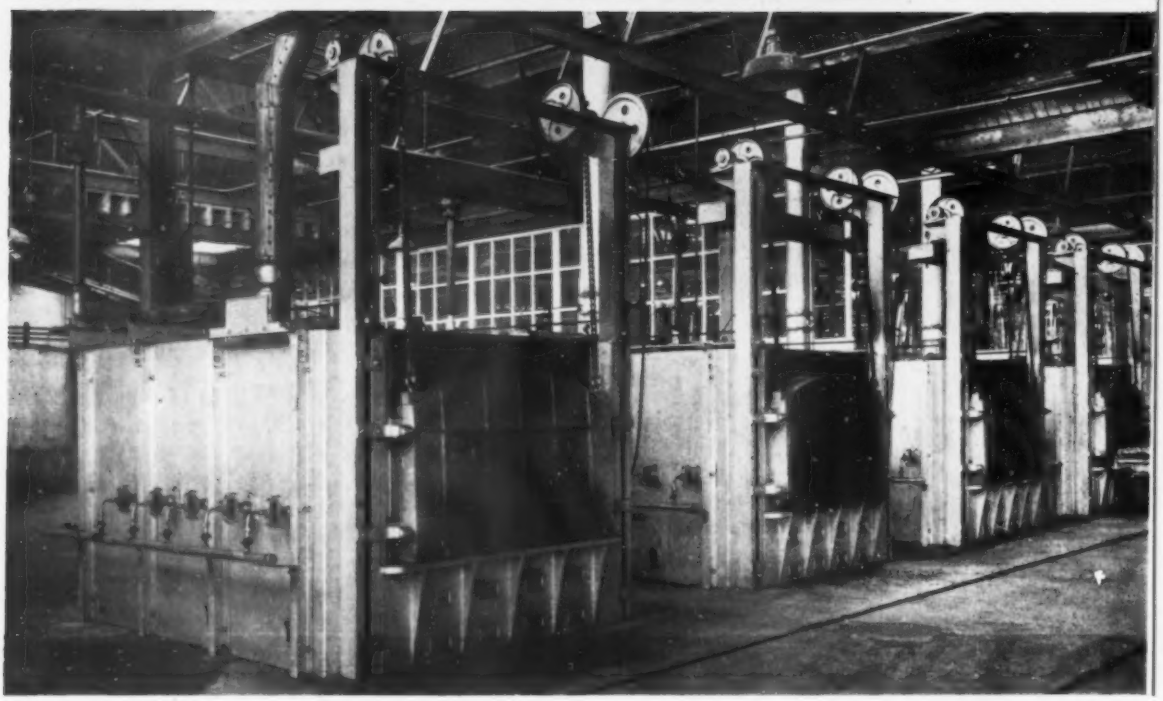

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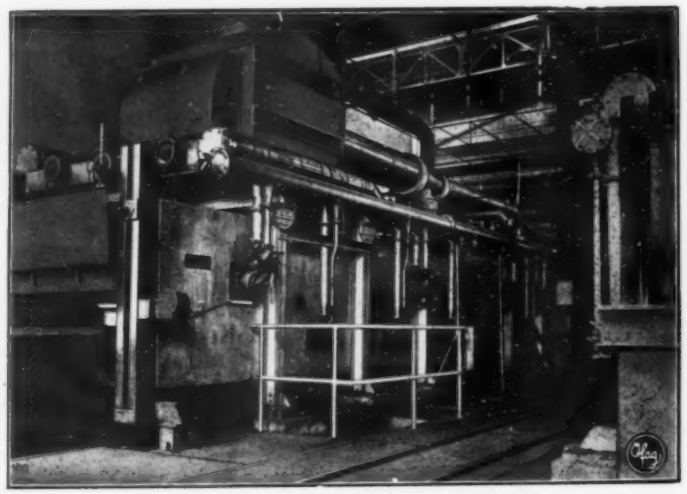

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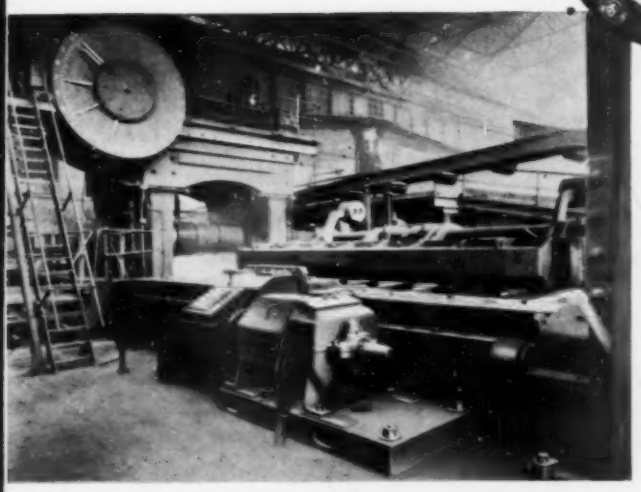

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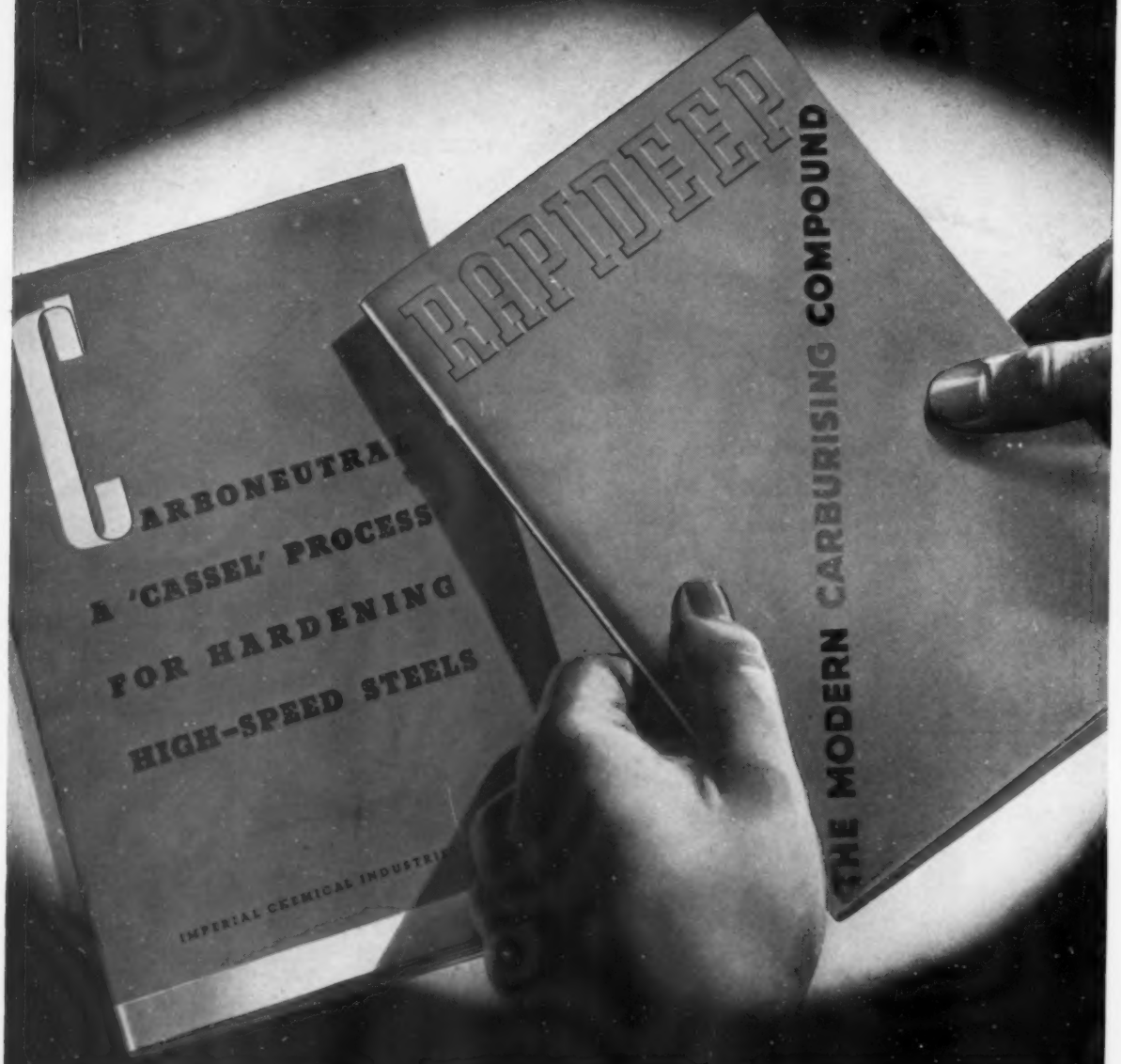

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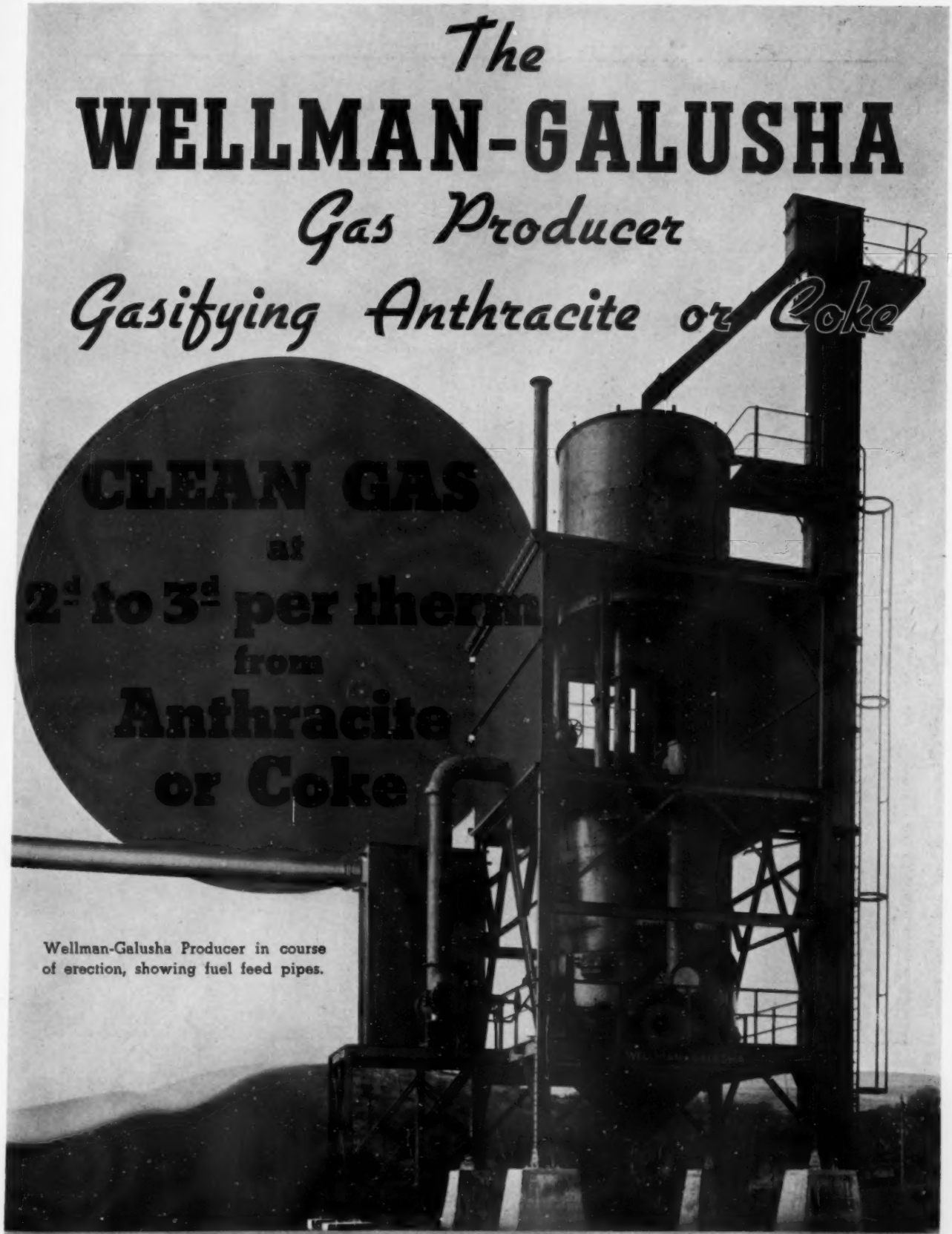

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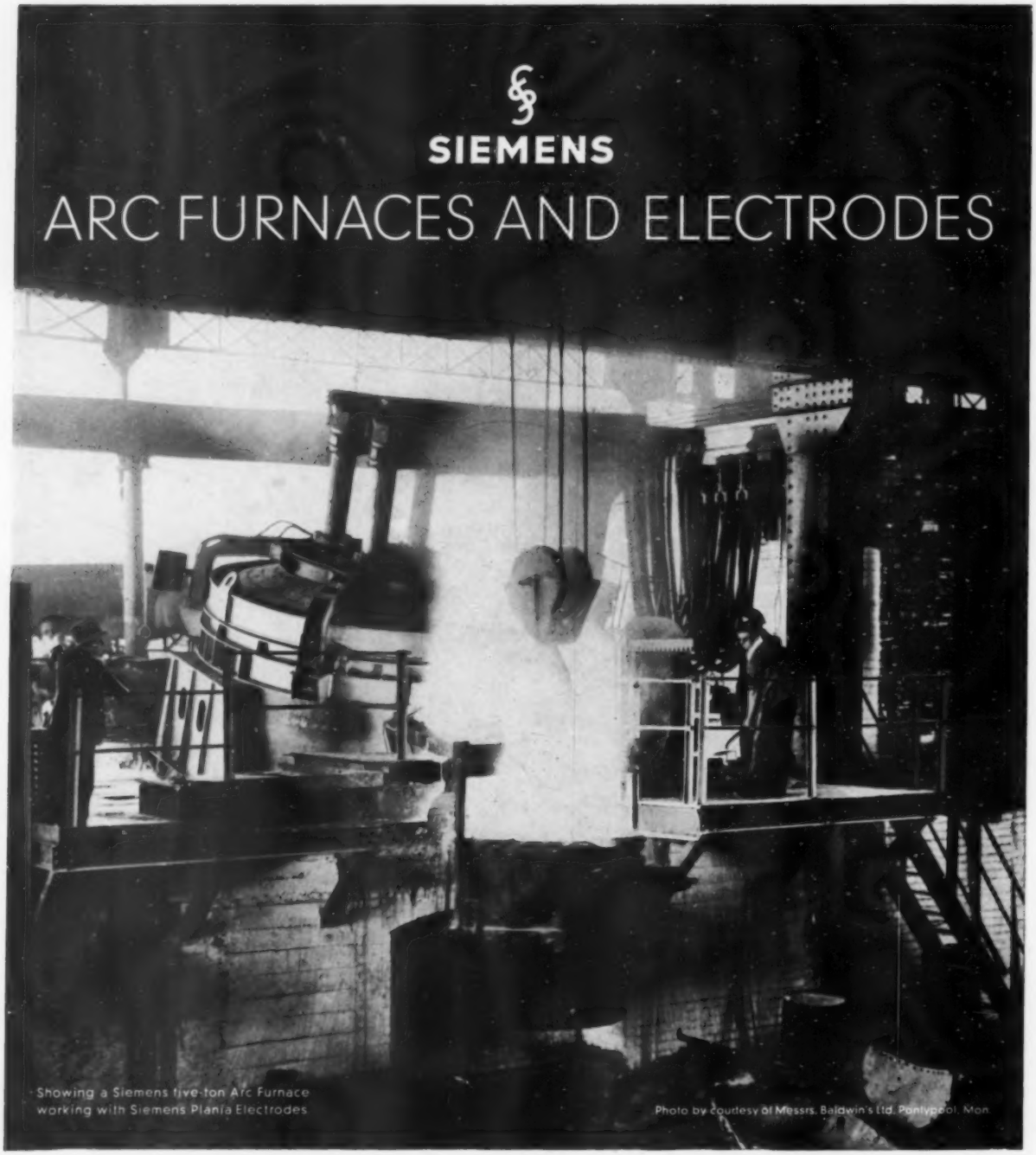
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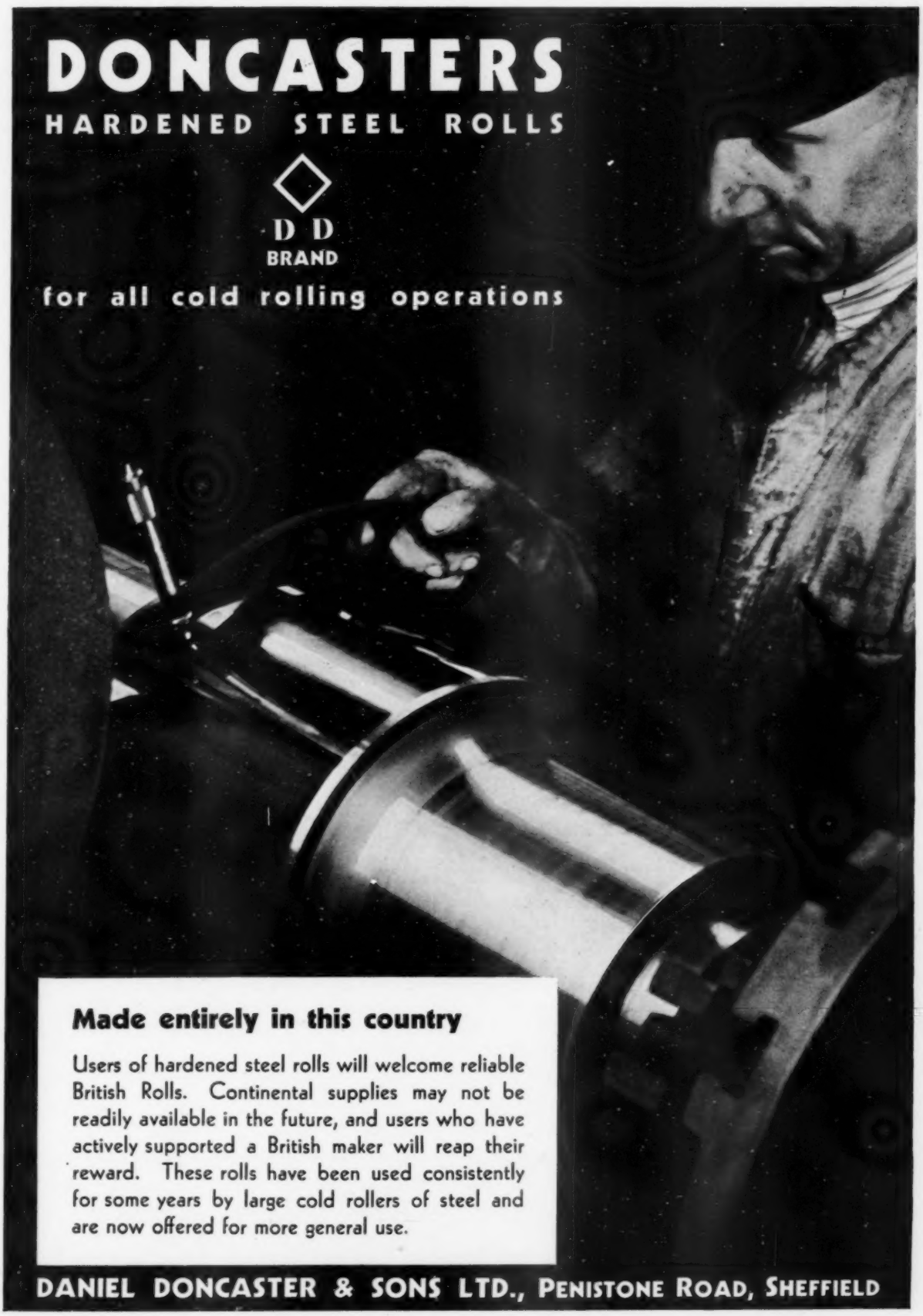

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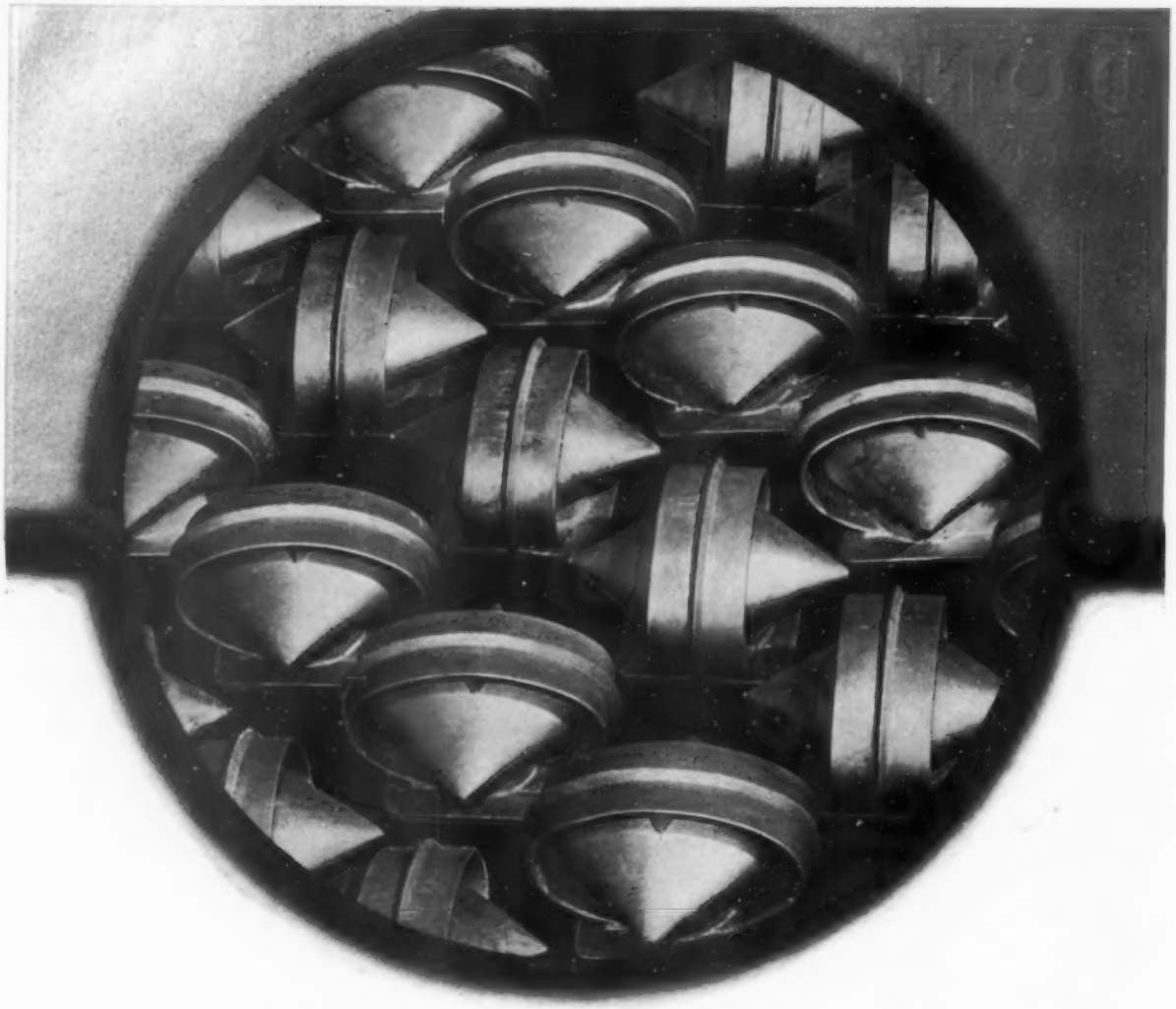

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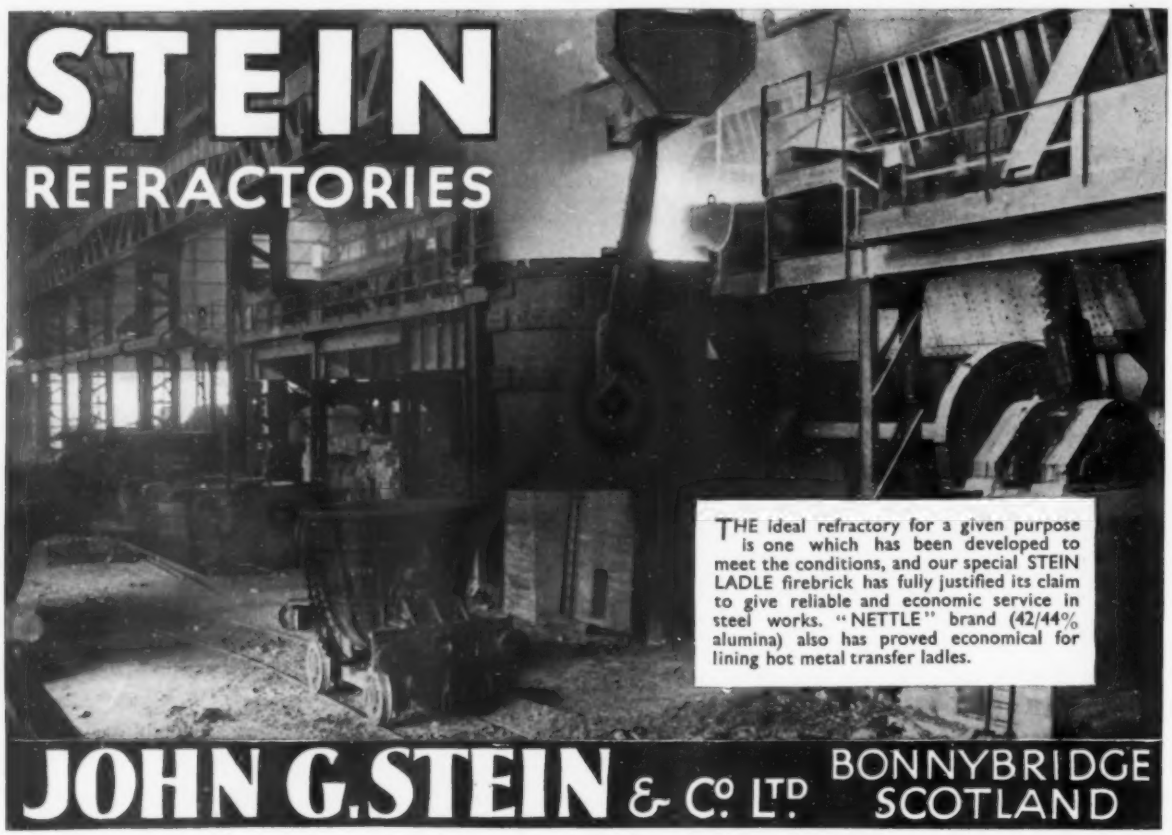
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FEBRUARY, 1938. VOL. XVII. No. 100.

Improvement of Open-Hearth Furnace Efficiency

By A. SMITHSON

Much thought has been given to the improvement of open-hearth furnace operations. With a view to obtaining greater efficiency, systems of control are discussed, with particular reference to the control of reversals, roof temperature, furnace pressure and combustion. Each system increases overall efficiency by maintaining the best condition relating to its particular function.

LONGER campaigns, maximum production, longer life of refractories, minimum fuel consumption—the constant aims of all open-hearth furnace users—are being obtained in many plants by carefully considered instrumentation. The factors combining to give these improved results—e.g., heat balance, furnace pressure, fuel-air ratio, etc.—cannot be correlated under any one control unit, but each can be independently controlled by one of the following systems:

(1.) Reversal control on the temperature difference basis.

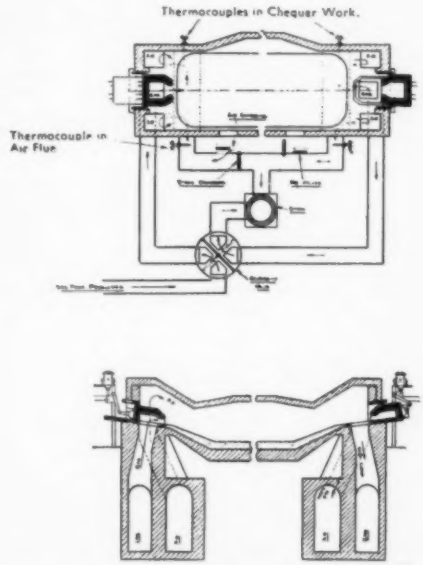


Fig. 1.—Open-hearth furnace. (Plan shows location of thermocouples.)

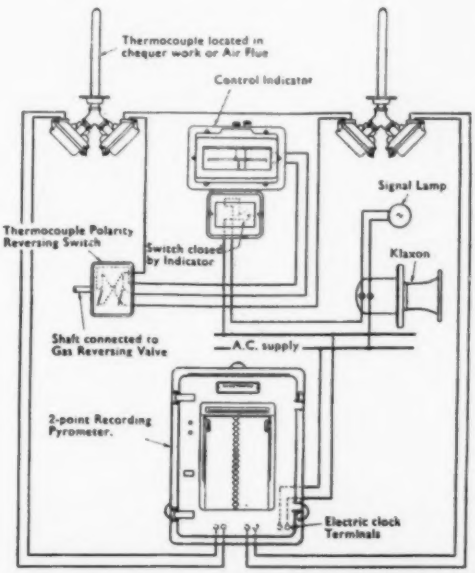


Fig. 2.—Temperature-difference system of regenerative furnace reversal.

(2.) Roof temperature control.
(3.) Furnace pressure control.
(4.) Combustion control.

In addition, instruments are available for checking draught and pressure conditions throughout the furnace system, providing valuable readings which facilitate considerably the operation of the furnace. A technical consideration of these control systems, and their advantages, will be of interest to all steelworks managers and metallurgists.

The Temperature Difference Method of Open-Hearth Furnace Reversal

It is agreed, universally, that reversal of an open-hearth furnace by "rule-of-thumb" methods is fundamentally unsound, the following example showing only one of the many disadvantages. It was noted that shortly after making a reversal, the chief melter left the stage and one of his assistants reversed again. This was unnecessary, and when asked his reasons for doing so, his reply was that in the absence of the chief melter he was responsible for the furnace reversals. He had, therefore, reversed the furnace in order that he should know "when to start counting."

The very object of reversal makes it obvious that it should be carried out on a temperature basis, and when the heat exchanges between the incoming gas and air, the waste gases, and the regenerator brickwork are becoming uneconomical. In a single reading, the temperature difference between the two sets of regenerators is the true criterion of such conditions, and has proved to be the most satisfactory basis on which to reverse the furnace.

Figs. 1 and 2 show a reversal signalling system, and will serve to demonstrate the method of operation. Two thermocouples are installed in the air flues, at the bases of the regenerators, and connected in opposition through a thermocouple polarity reversing switch to a control pyrometer, which is calibrated direct in temperature difference. When the desired predetermined temperature difference is reached, the controller operates, lights a warning lamp, and sounds an alarm or, alternatively, reverses the furnace automatically.

As a check on the operation of this reversal control equipment, a two-point recorder is connected to separate thermocouple elements in the same sheaths as the control thermocouples. This recorder also provides a useful indication of the condition of the regenerators.

Reversal Signalling v. Fully Automatic Reversal

Practical results have shown that this system of open-hearth reversal is indispensable to an acceptable standard of operation; but opinion is divided as to the relative

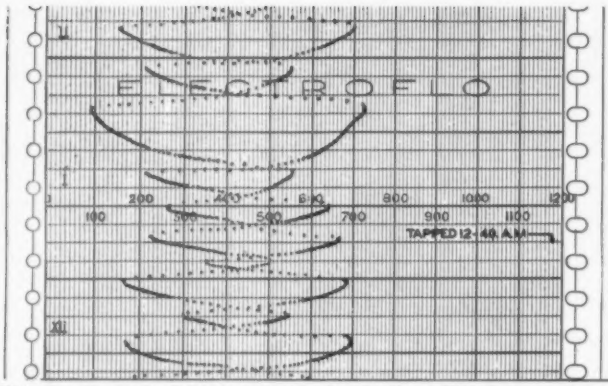


Fig. 3.—Record of temperatures in air flues just before the reversal signalling equipment was put into operation, the furnace being reversed on an empirical basis. The furnace is obviously unbalanced, and reversals are very irregular, due to the familiar human element.

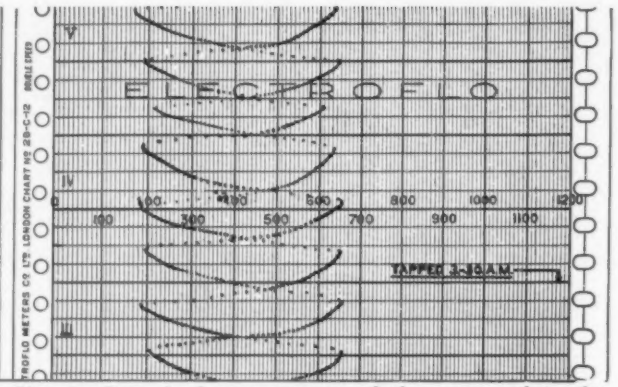


Fig. 4.—Record of temperatures of the same points the following day, a few hours after the reversal signalling equipment was put into operation. The reversals are regular and a uniform heat balance of the furnace is maintained, even through the tapping period. It will be noticed that the maximum useful regeneration is taking place.

merits of the signalling system and fully automatic reversal.

Some heats may be automatically controlled throughout, but such cases are exceptional. Generally, at times in a heat, it is necessary to delay or speed-up reversal to correct some undesirable condition in the furnace bath. At such times any control equipment must be ignored, and so, in effect, the fully automatic system becomes semi-automatic. To meet such emergencies in the fully automatic system, push-button controls are generally provided. This is clear indication that reversal cannot be controlled entirely automatically, and an admission of the partial failure of this system.

It has been claimed that with fully automatic reversal the time lost in reversing is reduced to a minimum, so that the heat losses by radiation are negligible. This point has perhaps been unduly stressed, because even with manual reversal the time taken is short, and in this case also the heat losses are negligible. Such losses are insignificant when compared with the continuous loss of sensible heat of the waste gases leaving the furnace, and the intermittent heat loss due to the preheated gas and air in one set of regenerators being expelled at each reversal. These form the largest proportion of the heat losses from the furnace, and are, moreover, common to both systems.

To sum up, the signalling system, because of its greater simplicity, lower cost and superior flexibility, would appear to be more suited to the complex process of steel making in the open-hearth furnace, and more likely to find favour in the eyes of discriminating metallurgists and engineers.

Thermocouple Locations—Why the Air Flues are Best

Some doubt has been expressed as to the suitability of the air flues or bases of the regenerators for the thermocouple locations, but these points were only selected after careful consideration and extensive experiments, for the following reasons :

(1.) At these points the waste gases are thoroughly mixed, and therefore at a true average temperature. Any temperature fluctuations caused by chemical reactions of the bath are dissipated in the passage of the gas through the chequer-work. It is only when such reactions are excessive that the effect is detected by an increase in the temperature of the gases in the flue, and they are then taken into account by the system.

(2.) The temperatures attained at these points are comparatively low (700° to 800° C.), so that robust base-metal thermocouples can be used.

(3.) The fluctuations in temperature at these two points, due to reversal, are greater than in any other part of the furnace system. This, together with the high e.m.f. developed by base-metal thermocouples, enables the temperature difference to be measured with extreme accuracy.

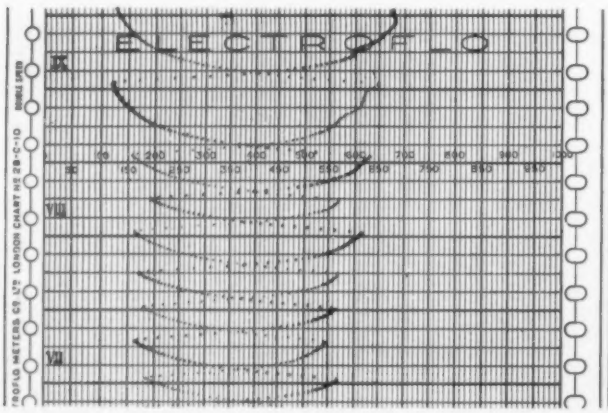


Fig. 5.—Record under conditions similar to those mentioned above, but at a different plant. Whilst the furnace is not so unbalanced the reversals are very irregular. Irregularity in the records above 600° C. indicates secondary combustion in the flues due to excess gas and inward leakage of air. It was subsequently found that the brickwork of the flues was in bad condition.

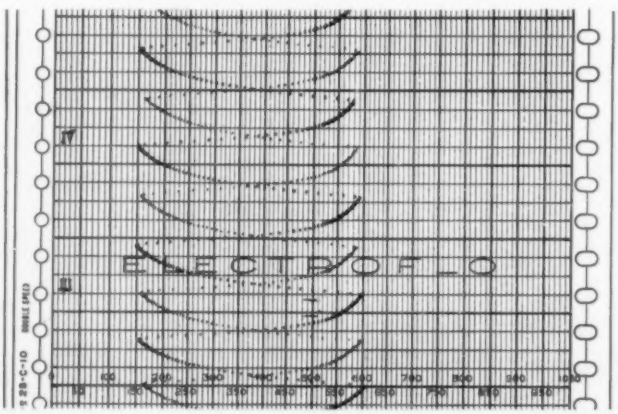


Fig. 6.—Record from same points just after the reversal signalling equipment was put into operation. Reversals are regular, and the furnace is evenly balanced. The secondary combustion is prevented by reduction of gas input on the basis of knowledge gained from the record shown on the left. It will be seen that reversals occur just before the heat-saturation point of the regenerators is reached giving maximum useful regeneration.

(4.) Since the temperature-e.m.f. relationship of base-metal thermocouples is linear, the control indicator gives true temperature difference readings, irrespective of the operating temperature ranges of the chequers.

It has been argued that the temperature of the thermocouple on the suction side falls to atmospheric temperature almost immediately after reversal. This may be true if the thermocouple is at the point of air admission, but in the selected position a cooling curve of the same characteristic as that of a thermocouple in the base of the chequers is obtained. It should be borne in mind that just after reversal the thermocouple is in a hot flue close to the base of the chequers, which are at a temperature of 700° to 800° C. It indicates the actual temperature of the brickwork, and not that of the ingoing air. In this connection it is interesting to note that the operating records shown in Figs. 5 and 6 were taken from thermocouples installed on the reversing valve-box—i.e., almost at the point of air admission.

When first considering the scheme, it may appear that the tops of the chequers are more suitable locations from which to measure the temperature difference. Such positions have been carefully considered and rejected because :

(1.) The operating temperatures are high (1,350° to 1,400° C.), and subject to fluctuations due to bath reactions.

(2.) The rare metal thermocouples, or radiation tubes, therefore necessary are not as suitable as base-metal thermocouples because :

(*a*) The temperature-e.m.f. characteristics are not linear, so that, although the e.m.f. required to operate the controller is constant, the actual e.m.f. available for a given temperature difference will vary in magnitude in accordance with the operating temperature ranges of the chequers.

(*b*) The available protection sheaths for rare metal thermocouples are rapidly attacked by dust and oxide particles carried over from the bath. Frequent breakdowns occur, and maintenance charges are high.

(*c*) Variable corrections are necessary to the readings of radiation tubes, depending on the condition of the sighting windows and the density of the fumes in the exhaust gases.

Longer Campaigns—Increased Production—Longer Life of Refractories—Lower Maintenance Costs—Reduction in Fuel Consumption

These inevitably follow the use of reversal-signalling equipment, primarily because the maximum quantity of waste heat is returned to the furnace and a uniform heat balance throughout the furnace is obtained.

The typical operating records—Figs. 3, 4, 5 and 6, taken before and after the installation of reversal-signalling equipment—clearly show the improvement effected in the uniformity of working. When these are considered in the light of practical experience, it becomes obvious that the above-mentioned benefits must be obtained with a consequent increase in overall furnace efficiency. Further proof is given in the following reports, which give the results of practical tests on different plants and different sizes of furnaces.

Report No. 1 : 80-ton Furnace

(The first campaign after installation of reversal-signalling equipment on 80-ton furnace, as compared with the previous campaign of the same furnace and identical furnaces operating simultaneously.)

Length of Campaign.—Forty-two weeks : furnace taken off owing to the choking of the chequers. If this trouble had not been experienced it is believed that the furnace would have run for over a year. In any case the 42 weeks is much above the average.

Output.—Increased by 0·31 casts per week, and since each cast corresponds to 80 tons, this gave a total increase in output of 24·8 tons per week, or approximately 1,000 tons increase in output for the complete campaign. Obviously a longer campaign gave a further proportionate increase in the output, but details of this latter increase are not available.

Life of Refractories.—The life was definitely better even although the refractories on this particular furnace were admittedly inferior to comparable furnaces.

Port Blocks.—The life of port blocks on the furnace under control was 14 weeks. The life of port blocks on the previous campaign on the same furnace, when not under control, was 12 weeks. This, therefore, represents a saving of between 16% and 17% on port blocks alone.

The saving in maintenance charges on the brickwork was approximately 16%.

Fuel Cost.—No definite comparison was made on the fuel consumption, but the officials concerned are quite confident that the saving was at least 5%, and may even be up to 20%.

Report No. 2 : 10-ton Furnace

While not so definite as Report No. 1—comparative figures of the previous campaign were not available,—the officials of the Company concerned confirm the results of Report No. 1, and state further that whereas before the equipment was installed they used to have cold casts, with waste of material, no such trouble is now experienced, and a very definite improvement in output has been obtained. It is reported that maintenance costs on the furnace brickwork have shown a considerable reduction.

Open-Hearth Furnace-Roof Temperature Control

For the roof of an open-hearth furnace—the portion of the furnace subjected to the most severe conditions, with the possible exception of the port blocks—the strength of the refractory at high temperatures and its softening point are of vital importance. With the materials at present available for roof construction, the high-operating temperature of the furnace leaves only a small margin of safety on these points.

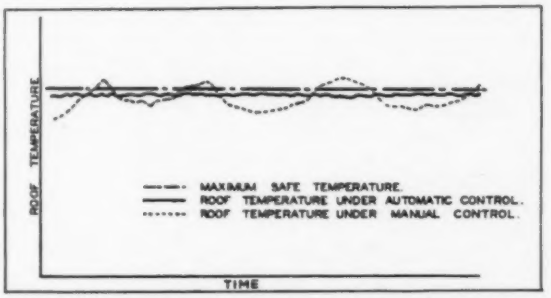


Fig. 7.—Open-hearth furnace roof temperatures.

There is a maximum roof temperature at which the furnace can be run with safety. Periods of even short duration at temperatures higher than this may be sufficient to cause serious weakening of the structure, although the roof temperature may be well below the " safe " maximum for the majority of the time (Fig. 7). Such short periods at too high a temperature are inevitable when the only precaution taken is occasional visual examination, which, after all, only registers such faults as " dripping " and " distortion " when they actually occur. The seriousness of such faults cannot be too strongly emphasised because they eventually necessitate expensive repairs, with consequent loss of production.

Exact knowledge of the roof temperature enables such peaks to be eliminated, and the furnace to be run up to the maximum safe temperature without any danger of roof collapse. Further, this temperature can be automatically controlled, or alarm equipment provided to indicate that this maximum has been reached, and so enable the operator

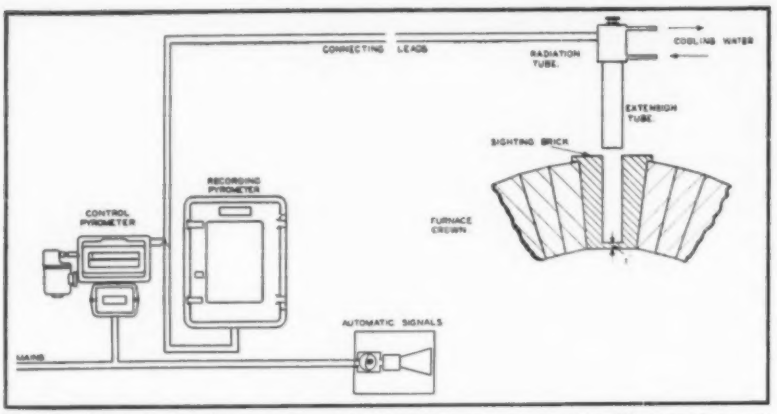


Fig. 8.—Diagrammatic arrangement of roof temperature signalling equipment.

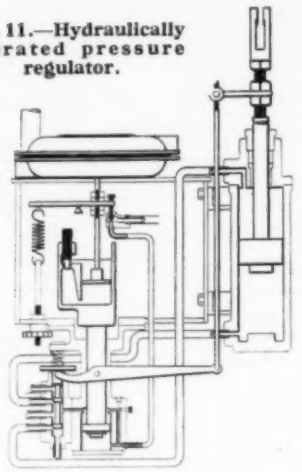


Fig. 11.—Hydraulically operated pressure regulator.

to take corrective action immediately. Moreover, his time is not spent in watching a temperature indicator or recorder, and such control or signalling equipment supplements his practical knowledge, which can be used to the best advantage.

Fig. 8 shows the schematic diagram of Electroflo signalling equipment. A carborundum block, with a central hole drilled to within 1 in. of the bottom, is built into the furnace roof, so that the inside is flush with the crown of the roof. A water-cooled radiation tube, with extension, is sighted on to the bottom of this hole, and is connected to an indicating control pyrometer and recording pyrometer, the two instruments being in parallel. The alarm signals are operated by the control pyrometer.

Unlike the case of reversal, there are here no serious difficulties to prevent the use of automatic control equipment operating directly on the gas supply. It is usually felt, however, that the cost and added complication of the valve-operating gear are hardly justified when the automatic signalling device is provided. This signalling equipment can always be adapted to provide an impulse for fully automatic valve operation if this is eventually required.

Whilst the operator's time need not be occupied in close examination of the roof, the signalling instrument and recorder ensure that an indication and record of the trend of the furnace temperature is always available. This enables him to *anticipate* any excessive temperature and supply corrective action, although the signalling device acts as a safeguard against any abnormal rise.

Roof-temperature control protects the furnace refractories from damage due to excessive temperatures, thus prolonging the campaign. Production is increased by the ability to run the furnace up to its maximum safe temperature. Improved furnace efficiency is inevitable.

Open-Hearth Furnace-Pressure Control

Expansion and contraction of the brickwork of an open-hearth furnace, due to the high and fluctuating temperature, result in cracks and fissures through which air can leak into, or hot gases be forced out of the furnace, depending upon the differential pressure between the bath and atmosphere.

A *positive* differential (excess pressure in the bath) causes :

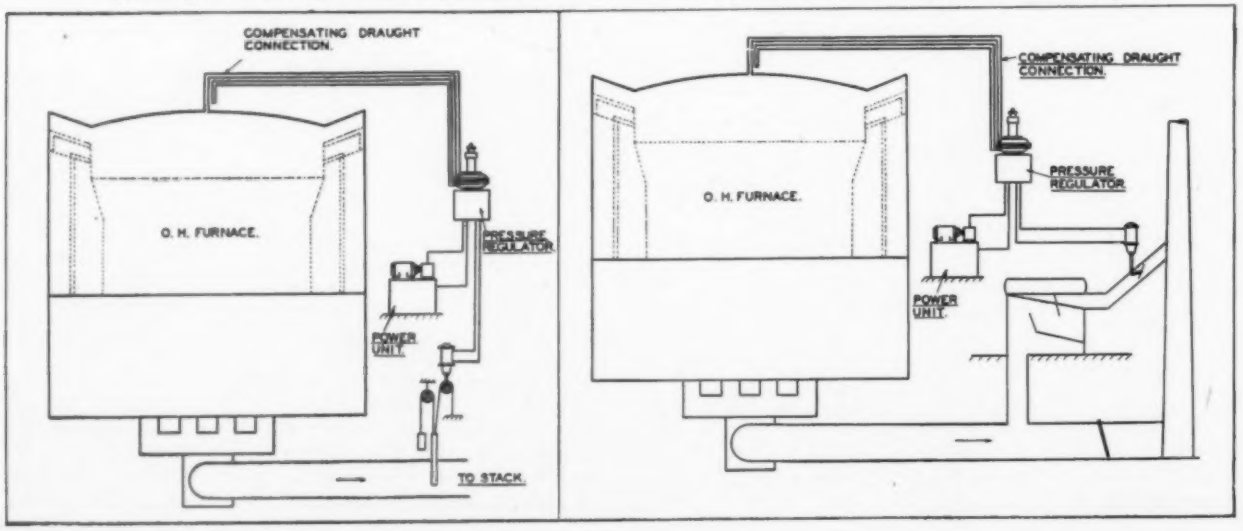
1. Danger due to flames during charging operations.
2. Hot gases to be forced out through faults in the brickwork, which becomes overheated and increases maintenance costs.
3. High waste-gas velocities which, in turn, mean :
   (*a*) Reduction in heat transfer from flame to charge.
   (*b*) Dust and oxide particles carried over from the bath settling in the chequers, eventually causing premature choking.

A *negative* differential (excess suction in the bath) causes :

1. Cold air to be drawn in, primarily through the charging doors and faults. The quantity is ever fluctuating, and may reach considerable amounts. Cold air chills the bath. More fuel is required to maintain the necessary temperature (experiments show that 10% excess air causes a drop in flame

Fig. 9.—Arrangement of furnace pressure regulator operating slide damper in waste gas flue.

Fig. 10.—Arrangement of furnace pressure regulator operating waste heat boiler outlet damper.



temperature of approximately 150° to 200° F.) This excess air is difficult to control, and combustion under best conditions is impossible.

2. Losses due to oxidation of charge.

For ideal working the pressure in the furnace should be atmospheric; but the problem is complicated because the pressure varies from point to point along the furnace, and the selected sampling location—generally near the centre of the roof—only serves as an index of the general conditions. Experience has shown that if the pressure at the bottom of the charging doors is to be atmospheric, a pressure of 0·04 in. to 0·05 in. w.g. should be maintained at the top of the roof. A slight change in this latter pressure raises or lowers the atmospheric-pressure level considerably; 0·005 in. w.g. increase, or decrease, in this pressure raises, or lowers, the level approximately 6 in.

A positive pressure under the roof can be maintained under normal manual control, but to do this to the degree of accuracy required is almost impossible without an automatic regulator which will respond to *every* pressure fluctuation. This necessity for maintained accuracy makes it essential that such a furnace-pressure regulator must be:

1. Sensitive to 0·001 in. w.g.
2. Powerful enough to move the heaviest dampers.
3. Rapid in operation.
4. Stabilised.

Fig. 9 shows a furnace-pressure regulator arranged to operate a heavy stack damper, while Fig. 10 shows a similar regulator adapted to a furnace equipped with waste-heat boilers. The details of the regulator itself are shown in Fig. 11. How completely this regulator meets the requirements listed above is illustrated by the following particulars:

1. A super-sensitive diaphragm of low inertia is fitted. This responds to pressure changes of the order of 0·0005 in. w.g. instantly, and thus follows every impulse of the furnace.
2. A hydraulic power unit supplies high-pressure oil to a power cylinder capable of lifting dampers weighing several hundredweights.
3. This regulator will meet any speed requirement up to one full stroke in 2·4 secs.
4. A stabiliser of the dashpot and plunger type prevents overtravel or hunting. This stabiliser exerts a force on the weighbeam in opposition to the force exerted by the diaphragm. This force is created by the upward travel of the amplifier piston, which causes an increase in the oil pressure under the stabiliser plunger, forcing it upwards. This pressure is gradually relieved by the flow of oil through the restricted orifice to the chamber above the plunger.

A useful addition to any furnace-pressure regulating equipment is a draught recorder for checking the operation; it is essential, however, that this draught recorder should have a similar sensitivity to the regulator diaphragm.

Combustion Control

Another particularly useful application of regulating equipment on an open-hearth furnace is for the control of the fuel/air ratio. The value of correct proportioning of the gas and air supplies cannot be over-estimated, since it affects a number of conditions resulting in:

(1) Maximum flame temperature.
(2) Low flame velocity—giving maximum heat transfer from flame to charge and minimum carry-over of dust and oxide particles to the chequers.
(3) Flame being kept down on to the charge, helping to prevent over-heating of the roof.
(4) Elimination of soot and dust in chequers and flues.
(5) The maintenance of the correct atmosphere over the bath for the chemical reactions to take place at the correct rate.

The principle (shown in Fig. 12) is that both gas and air supplies are accurately measured by means of calibrated

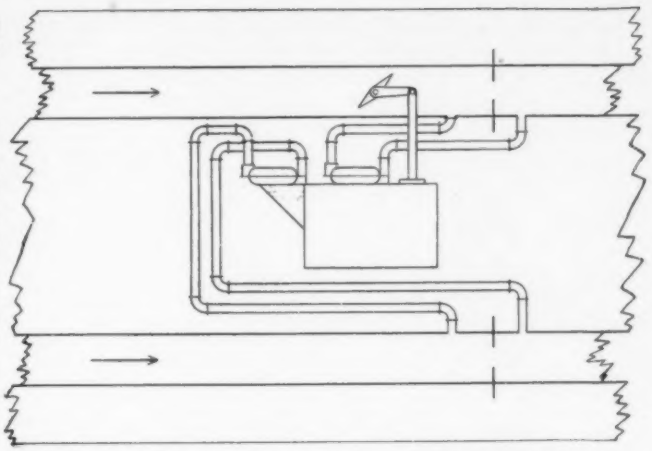


Fig. 12.—Diagrammatic arrangement of ratio regulator.

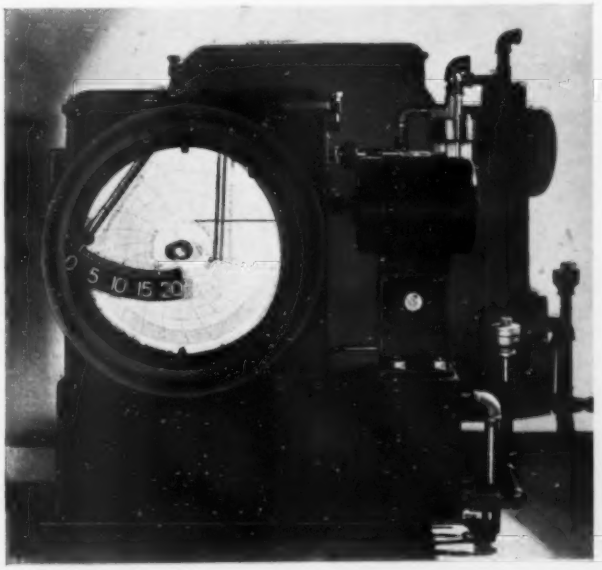
orifices, and the flow of air regulated in proportion to the flow of gas in that ratio required to ensure efficient combustion.

The measurement of CO_2 in the waste gases from the furnace provides a useful check on the combustion efficiency, provided account is taken of the evolution of CO_2 from the chemical reactions in the bath. The CO_2 indicator and recorder shown in Fig. 13 is particularly suited to the severe working conditions, and, in fact, meets the ideal specification for such an instrument drawn up by prominent steelworks metallurgists, except in the speed with which the reading is given after sampling. This discrepancy from the ideal specification is only a matter of seconds, and, as such, is not of extreme importance.

Conclusion

The systems of control discussed—i.e., reversal control, roof-temperature control, furnace-pressure control and combustion control—will individually increase the overall furnace efficiency by maintaining the best condition relating to its particular function. The installation of one system of control may bring about such economies as to make it seem uneconomical to install the others; but such a system of approach is conservative, and implies little confidence in regulating equipment. Over-elaboration, on the other hand, is by no means desirable, but careful thought and simple experiments will show which of these systems are likely to prove most economical on any particular furnace.

Fig. 13.—Industrial CO_2 indicator and recorder.



Marketing Beryllium and its Ores

BERYLLIUM, or glucinum, as it is called in England, is a very light metal, having about the same density as magnesium. Although as rigid as steel and possessing other interesting properties in its unalloyed state, it seems destined always to be too expensive to be used extensively except as a hardening agent for other metals. At present the rather small amount of beryllium consumed is principally in the form of beryllium-copper alloys, containing about 2·5% beryllium, and having a wide variety of applications. A great deal of publicity, states Mr. Paul M. Tyler, Chief Engineer, Nonmetal Economics Division, U.S. Bureau of Mines, has been given the light-metal alloys of beryllium and their possible use in aircraft, but commercial developments in this field so far have been unimportant. More promising is the use in iron alloys, particularly nickel-iron and nickel-chrome-iron, and in Germany nickel-beryllium alloys are made commercially. Beryllium oxide and sundry other compounds likewise have highly useful properties.

Master alloys have been produced in the United States by at least three companies, and a number of others have experimented with making the metal or its alloys or compounds, but only a fraction of the present capacity of, say, 200 lb. a day, is actually utilised.

Late in 1936 the price of beryllium-copper master alloy was reduced to $23 per lb. of beryllium content. The metal, although not produced in the United States, is available in laboratory quantities for around 500 marks per lb. Beryllium oxide, fluffy, 99·8%, calcined at 1,450° C. for refractory crucibles and electrical insulators, can be bought at $4 per lb. in 100-lb. lots.

The only commercial ore of beryllium is beryl, which occurs in commercial quantities only in pegmatites, and occasionally is a by-product of feldspar- or mica-mining. This extraordinarily hard mineral is a beryllium-aluminum silicate that contains theoretically about 5% of the element or 14% of the oxide BeO. Nominally quoted at about $30 a ton for the 10% BeO grade, and $35 a ton for the 12% grade f.o.b. mines, or, say, $50 at New York, beryl is currently offered somewhat in excess of the ability of the consumers to absorb, but, paradoxically, if a much larger supply were positively assured, demand, and possibly prices as well, would tend to increase. Ore supplies have long been a deterrent to more rapid growth of the industry, but consumers now seem to feel that no real difficulty should be experienced in obtaining regularly 500 to 1,000 tons annually, which is two or three times present consumption in this country.

Domestic production hitherto has come mainly from South Dakota. Imports have come principally from British India, but the 162 short tons of beryl imported in 1936 were almost all from Argentina. Brazil, Union of South Africa, and Madagascar are other sources, and, outside of the United States, Germany and Italy appear to be leading buyers of beryl.

Royal Aeronautical Society Awards

THE Council of the Royal Aeronautical Society have awarded the Simm's Gold Medal to Dr. N. A. de Bruyne for his paper on plastic materials for aircraft construction; the Taylor Gold Medal to Mr. George Mead, for his paper on power plant trends; the Wakefield Gold Medal to Dr. G. V. Lachman for his paper on aerodynamic and structural features of tapered wings; The Edward Busk Memorial Prize has been divided between Major B. C. Carter and Mr. A. G. Pugsley, for their papers on airscrew-blade vibration and control surface of wing stability problems, respectively; and the Pilcher Memorial Prizes to Mr. A. J. Hanson and Mr. C. O. Vernon, for their papers on critical speeds of monoplanes and aircraft performance estimation, respectively.

Forthcoming Meetings

ROYAL AERONAUTICAL SOCIETY.

Mar. 3. "Riveting Methods in German Aeroplane Construction," by Dr.-Ing. W. Pleines.

INSTITUTE OF METALS.

Mar. 8, 9, and 10. Annual General Meeting in the Hall of the Institution of Mechanical Engineers, London, S.W. 1.

BIRMINGHAM SECTION.

Mar. 3. "Non-destructive Testing," by J. P. Reed.
Mar. 15. "High-Speed Strip Rolling," by C. E. Davies, A.M.I.Mech.E.

LONDON SECTION.

Mar. 3. "Plastics," by N. J. L. Megson, M.Sc.

NORTH-EAST COAST SECTION.

Mar. 15. "Magnesium Alloy Castings," by O. Kennedy.

SCOTTISH SECTION.

Mar. 14. "What Conventional Properties Tell Us About Materials," by G. W. Austin, O.B.E., M.Sc. Annual General Meeting.

SHEFFIELD SECTION.

Mar. 1. "Electro Deposits: Chromium, Rhodium, Cadmium. Some Difficulties and Suggestions," by Frank Mason.

SWANSEA SECTION.

Mar. 15. "Recent Developments in the Production of Copper," by R. D. Burn, M.Sc.

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.

Feb. 25. "Special Steels and Their Application to Engineering and Shipbuilding," by Dr. T. Swinden.

INSTITUTE OF MARINE ENGINEERS.

Mar. 8. "Materials for High-Pressure Steam Conditions," by R. W. Bailey, D.Sc.

MANCHESTER METALLURGICAL SOCIETY.

Mar. 2. "Some Researches into the Mechanism of Corrosion," by U. R. Eans, D.Sc., M.A.
Mar. 16. "Ingots and Ingot Defects," by H. H. Burton.

INSTITUTE OF BRITISH FOUNDRYMEN.

BIRMINGHAM BRANCH.

Mar. 4. "Shrinkage and Contraction of Cast Iron," by A. A. Timmins, A.I.C.

EAST MIDLANDS BRANCH.

Feb. 26. Annual Dinner (at Derby).

LINCOLNSHIRE SECTION.

Mar. 14. "Foundry Sands," by B. Hird.

LANCASHIRE BRANCH.

Mar. 5. "Some Fundamental Properties of Moulding Sands," by W. J. Rees, M.Sc.

BURNLEY SECTION.

Mar. 8. I.—Annual General Meeting.
II.—Two Short Papers by Students.

LONDON SECTION.

Mar. 2. "The Production of 'Pressure-Tight' Castings in Grey Iron and Its Alloys," by A. E. McRae Smith, M.A.

MIDDLESBROUGH BRANCH.

Mar. 11. Annual General Meeting.
Mar. 18. "Corrosion-Resisting Cast Iron—Its Production and Use," by F. Hudson.

NEWCASTLE-ON-TYNE BRANCH.

Feb. 26. "The Toughness of Cast Iron from Transverse Stress Strain Curves," by G. L. Harrach.

SCOTTISH BRANCH.

Mar. 12. I.—"The Fitting Shop," by J. Cameron, Jun.
II.—Annual General Meeting.

FALKIRK SECTION.

Mar. 5. "Patternmaking in a Light Castings Foundry," by R. R. Shaw.

SHEFFIELD BRANCH.

Mar. 3. "Steel Castings," by J. Deschamps.

WALES AND MONMOUTH BRANCH.

Feb. 26. "More Non-Ferrous Problems," by F. Dunleavy.

WEST RIDING OF YORKSHIRE BRANCH.

Mar. 12. "Moulding Sands," by A. W. Walker, and S. Carter.

METALLURGIA
THE BRITISH JOURNAL OF METALS.
INCORPORATING "THE METALLURGICAL ENGINEER"

Aluminium—Its Discovery and Development

FROM a laboratory curiosity (about a hundred years ago, when it was first isolated) aluminium is now applied to such wide and varied purposes that to-day, in point of tonnage, it ranks as fifth of the world's metals. For many years, following its isolation, progress was difficult and slow, largely due to limitations of knowledge and facilities then available to investigators. Only since the discovery of the electro-metallurgical methods by Hall and Héroult, in 1866, has real progress been made in the consumption of aluminium, because these methods facilitated the commercial production of the metal and substantially reduced the cost. Thus it can be said that the present level of consumption has been achieved in about fifty years—a remarkable achievement, to which practically all industrialised countries have contributed.

The early work involved in the production of aluminium is an interesting story. It is believed that F. Hoffman, in 1722, first premised that alum had a separate base, for which the French chemist, Guyton de Morveau, suggested the name alumine, the French expression for alum being "sel alumineux." More than a century elapsed before the metal was isolated. Davy, in spite of his success with sodium and potassium, was unsuccessful in isolating aluminium; although he obtained an alloy of aluminium and iron, which he named alumium, but subsequently changed the name to aluminum, the name which is preferred in America; in England, however, the name was changed to aluminium.

The first step towards the production of this metal on a practical scale was made by the Danish physicist, Oerstedt, in 1825, when he obtained aluminium chloride. Two years later the metal was isolated by Wöhler, at Göttingen, but the small globules he produced were much contaminated with other substances; in 1845, however, Wöhler was not only able to produce purer metal, but sufficient to carry out physical tests.

Considerable impetus to the commercial production of aluminium was given by the work of the French chemist, R. St. Clair Deville. In 1854, unaware of what Wöhler had done, Deville repeated the latter's experiment, using aluminium chloride with potassium, and an electric current through carbon and platinum poles. As the reducing agent Deville found potassium too expensive for commercial purposes, whilst the electric current of his day, depending on the decomposition of zinc, was also too costly. Deville, however, had invented a relatively cheap method of producing sodium, and, finding that sodium could take the place of potassium in reducing aluminium, he devised two processes for obtaining the latter metal, one of which remained for many years the sole means of producing aluminium on a commercial scale. The materials used by Deville were aluminium chloride, common salt, fluorspar and a form of alumina, or cryolite, a compound of aluminium and sodium chloride from Greenland. In 1855 Dr. Percy obtained aluminium directly from cryolite, thus showing the possibility of dispensing with the troublesome process of forming the double chloride.

The purely chemical processes of manufacture have long been discarded in favour of electro-metallurgical methods, rendered possible by the electric dynamo. The first inventors to devise a practical scheme for the production of aluminium by these methods were E. H. and A. H. Cowles, who established works at Milton, in Staffordshire, and at Lockport, New York. Another process, devised by Adolphe Minet, was tried on a large scale by the Brothers Barnard in France. Both processes were abandoned on the appearance of the system with which the names of C. M. Hall, of the United States, and P. L. T. Héroult, of France, are associated. These two investigators, unknown to each other, invented almost the same method about the same time; Hall applying for his patent in America, and Héroult in France and England, and the production of metallic aluminium is practically the same as originally described in these patents. The method consists in passing an electric current through a bath composed of alumina (Al_2O_3) and molten cryolite, a double fluoride of aluminium and sodium. The method involves the electrolysis of a molten electrolyte in a furnace or cell. The molten cryolite, at the bottom of the cell, forms the cathode, in which the reduced aluminium from the alumina charge is deposited, and the anode consists of rod, or rods, of graphite or carbon, which is consumed by the oxygen given off from the charge.

It is largely upon the pioneer work involved in the cheaper production, resulting from the Hall-Héroult processes, that the aluminium industry has made such rapid progress. Gradually at first, the advantages of this metal began to be appreciated as applications for it were demonstrated. Alloyed with copper it presented an attractive appearance, which found acceptance as a new bronze; but initial efforts were concerned primarily with reducing the cost of production so that the metal could more nearly approach the competitive cost of other metals. Efforts were also directed towards introducing it in marketable forms corresponding with other metals. At first it was marketed only as ingots, in which form it had more limited applications; gradually, however, sheet aluminium was produced, and, later, wire for electrical conductors, as well as tube. The discovery that aluminium was especially suitable for cooking utensils assisted the early development and application of the metal; but a greater impetus to development resulted from the introduction of motor transport.

The relatively low strength of aluminium undoubtedly retarded its application for many purposes, and while some progress was made in increasing strength by using copper as an alloying element, the discovery, by Alfred Wilm, in Germany, that an aluminium alloy, containing 4% copper, 0·5% magnesium, 0·5% manganese, and the remainder aluminium, could be hardened proved to be a development of major importance, and gave an impetus to research which rapidly intensified. This discovery, made during investigations carried out between the years 1903 and 1911, greatly increased the scope for aluminium. Even in 1900 production reached only about 7,000 tons; to-day, the figure is approaching 500,000 tons per annum, and in the Supplement, published in this issue, an effort is made to review the revolutionary progress of this metal. All industrialised countries have contributed to this progress, but the developments achieved in the several countries given are typical.

Platinum Metals in 1937

Increase in the Use of Palladium

DURING the past year the production of the platinum metals was 430,000 troy ounces, the largest single source being their recovery as part of the Canadian nickel operations. The demand for platinum declined slightly, but an increase in the consumption of palladium resulted in a total production figure for this group of metals approximating to that of 1936.

Although less platinum was used, primarily because of reduced activity in the jewellery trade, certain industries took more than usual, important examples being the chemical, electrical and dental fields. Platinum-clad materials used in chemical processes absorbed an increasing amount and colloidal platinum was produced commercially last year for the first time. This last material is proving of importance in research work and it is expected that it will not be long before certain industries will be able to utilise its properties to advantage.

The consumption of platinum alloys is still maintained in such well known applications as magnetic contact points, thermostatic control unit parts, circuit breakers and pyrometer equipment, where platinum-iridium is used. The demand for platinum-gold in rayon spinnerets has increased and another platinum alloy is used for the dies employed in the production of glass fibre for insulation purposes. This is a new development which was originated in America and is now being adopted in glassworks in other countries.

Palladium is receiving growing recognition as an important metal and its development has been stimulated to some extent by the high price of gold and gold restrictions generally. The consumption of palladium rose by 25% last year and this lesser known metal is now being widely used in industrial and decorative applications and in dental work.

It is interesting to recollect that the first experiments to replace the precious alloys by base metal alloys for orthodontic work originated in Germany, which has now returned to the use of palladium-silver and palladium-silver-gold alloys. Other palladium alloy applications of interest are contact points for high-speed telegraph relays, voltage regulators, and a new palladium-silver alloy for fountain pen nibs.

The continuing use of rhodium electroplate as a tarnish-resisting finish for sterling silverware has been an important factor in maintaining the consumption and the price of this platinum metal.

Scotland's Empire Exhibition

FROM May to October this year, Glasgow is to be the venue of an Empire Exhibition which will be the largest held anywhere since the famous British Empire Exhibitions at Wembley in 1924 and 1925. Scotland is condensing one-quarter of the earth's surface within a space of 175 acres, and in that space demonstrating not only the art, the culture, and the products of the Empire, but the way in which its peoples live and think.

The Exhibition will take place in Bellahouston Park, in the City of Glasgow. The Home Country will have its own vast pavilion. Canada, Australia, New Zealand, South Africa and the Irish Free State will be there. Along Colonial Avenue will be the pavilions of the West African Colonies, Southern Rhodesia, the East African Colonies, Malaya, the West Indies, and the rest. And Scotland, as host to the Empire, will have a separate display, both in its two pavilions and in the village transplanted from the Highlands for the occasion. There will be a palace of Arts and a Concert Hall. Three huge palaces will show the products of engineering and industry, and over 40 pavilions those of individual manufacturers.

All Scotland is behind this Exhibition, and she offers a warm welcome to the world to visit her during the period it will be open.

Steam Raising on Modern Liners

THE Institute of Marine Engineers added yet another to its series of papers dealing with the future of marine propulsion in a recent symposium by Professor A. L. Mellanby, D.Sc., LL.D., dealing with service results of high-pressure boilers. There is much behind this prosaic title which reflects on the type of power plants of the future. The old idea of placing water in a vessel and applying heat to boil the water, and then tapping the steam so formed, from the energy point of view is gradually dying. Such methods are too slow, clumsy, uneconomic and inefficient. Speed is the order of the age, and the modern type of steam-raising plant bears a relationship to the engine that it operates much the same as does the fuel valve of an internal combustion unit, and produces steam from dead-cold in a matter of a few minutes, thus conferring considerable flexibility on the power plant.

A number of such high-pressure boilers have been built and installed during the last few years, and it was the object of Professor Mellanby to deal with those which have had actual marine experience, and to analyse the results that they have obtained in service, from a practical standpoint. The Institute of Marine Engineers are to be congratulated in this respect, because they are supplying to the technical world some information which may guide shipowners and their advisers as to the choice of high-pressure boilers to use in the future. These high-pressure boilers represent a step ahead of conventional water-tube boilers as found in many big ships to-day. Many people consider them very theoretical : it is only an examination of this nature which can prove their true worth.

Activated Carbon

ONE of the most vital products for the defence and general safety of Great Britain is activated carbon, used for gas masks. It will be remembered that charcoal (carbon), made by carbonising wood, absorbs gases to some extent because of its cellular nature. Activated carbon is a very special form of carbon which possesses the power of absorbing gases to an enormously greater degree than charcoal, and was first produced for this purpose in the World War. As a filling for gas masks its function, along with a suitable incorporated filter, is to remove all poisonous and dangerous gases from the air before breathing, thus ensuring complete safety.

Some other uses are for decolorising liquids and the recovery of solvents and vapours from the air or gases.

Although activated carbon is manufactured in Great Britain, it has been stated that a large amount of the material is being imported from foreign countries. We are informed, however, this is absolutely untrue, as the amount imported is extremely small, and almost the total requirements are already being manufactured in Great Britain. Also, when the demand for civilian gas masks is satisfied there will be an enormous potential output available for ordinary commercial purposes.

One well-known Lancashire firm, who are the pioneers in this field and the largest manufacturers in the world of activated carbon, are turning out a huge amount of high-grade material, and have been engaged in its manufacture since 1914. Cocoanut shell charcoal usually constitutes the raw product for gas mask carbon, but the above firm have developed processes whereby all varieties are made from British coal, so that, in case of war, home supplies of raw material are available in unlimited amount.

So far as the manufacture and use of activated carbon is concerned, Britain also now leads the world.

Personal

Mr. Anthony E. Lowther, of Askham Hall, Penrith, has joined the Board of the Workington Iron & Steel Co. Ltd.

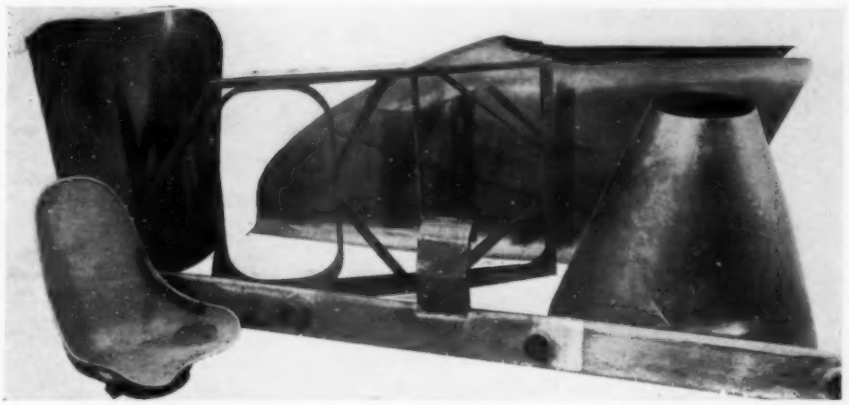
Recent Progress in the Application of Magnesium Alloys

By D. B. Winter, A.F.R.Ae.S.

Great development in the use of magnesium has been effected in this country in recent years and much work has been done in the development of suitable alloys. In this article particular attention is directed to alloys of the Elektron group and the great increase in the fields of their application is reviewed, together with future trends.

THE rapidly increasing use of magnesium alloys in England and all other industrial countries with the exception of Germany, has been caused by one factor only—their qualities favourable for industrial purposes.

Germany was the originator of the "Elektron group" of alloys and is now the highest consumer of them — followed by Great Britain. Years of development work were spent before the alloys were rendered economically valuable. It is an important point that suppliers of Elektron in this country have full access to the valuable experience gained by the I.G. Farbenindustrie A.-G. in Germany on the metallurgy of the metal and on its sphere of applications. Within the last few years the self-sufficiency plan has caused intensification of the development work in magnesium alloys in that country, particularly in the Elektron group, with the result that having undergone severe service testing, they are now being used to an increasing extent in all industries—especially aircraft and automobile. The German production of Elektron alloys has increased to an enormous extent in the last few years and is now in the neighbourhood of 20,000 tons per annum.



By courtesy of the De Havilland Aircraft Co. Ltd.

Examples of Elektron supplied by James Booth & Co. (1915) Ltd., and used in the famous D.H. Comet.

In 1936 the demand in England for Elektron alloys had reached such great proportions that Magnesium Elektron Limited commenced the erection of a factory for the manufacture of the alloys. This plant, subsequently, has been working to its maximum capacity of 1,500 tons yearly, and early this year, when the factory is completed, the annual output will be about 4,500 tons, which will render us completely independent from the point of view of supply. A quantity of 6,000 tons of Elektron alloys have been supplied to the English industry within the last few years.

The active research into the alloys, carried out in England by :—

Magnesium Elektron Ltd. ;

F. A. Hughes and Co. Ltd., (in collaboration with its licensees, Messrs. Sterling Metals Ltd., Birmingham Aluminium Casting (1903) Co. Ltd., J. Stone and Co. Ltd., Jas. Booth and Co. (1915) Ltd.) ;

has kept pace, year by year, with the increasing demands made by the engineering industry. This research has been, and is being, rewarded constantly by the discovery of new favourable alloying elements, new fabricating processes and treatments, etc., which improve such qualities as strength, ductility, resistance to corrosion, machinability, etc.

Main Advantages

The main advantages possessed by the magnesium alloys over those of other metals are :—

1. Low specific gravity (1·8) and high strength/weight ratio ;
2. Good machining qualities, which exceed those of all other metals ;
3. High resistance to fatigue ;
4. High heat conductivity ;

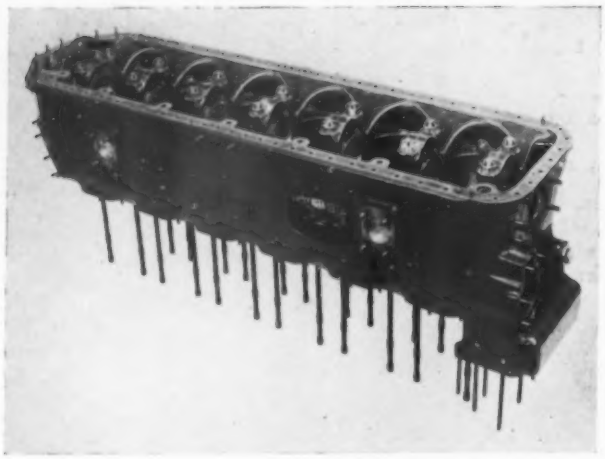
and other favourable properties which exist for individual forms of the alloys, such as ; for castings, ease of casting, freedom from pinholing ; for sheet, ease of welding ; for forging, ease of deformation, etc. These qualities have led to the substitution of the alloys for those of aluminium and steel, and also for brass, zinc, wood and other synthetic materials.

Fields of Application

Recent research has not only resulted in improvements in the alloys themselves but has evolved new special purpose alloys and new methods of surface treatments. Lacquers are now available which have been tested by exposure to sea water spray for many months in all climates and which have afforded complete protection for the metal over and above that given by the normal chromate treatment. The lacquers developed for protection of sheet are elastic to a high degree, have great adhesive qualities and a hard surface which will withstand very rough treatment. It is impossible for these lacquers to be chipped or peeled off.

The qualities of the alloys and the lacquers have been responsible for the use of the alloys in an increasing sphere of applications. The main fields of application can roughly be divided into the following :—

1. Highly stressed structural components of prime movers for which strength/weight ratio must be large, such as : crankcases for car and aero engines, engine bearers, bearing housings, gear-boxes, induction covers, etc.
2. Reciprocating and rotating components of machinery whose moment of inertia must be small. Such as, airscrew blades, aircraft and automobile wheels, moving parts of printing, cigarette and spinning machinery, etc.
3. Bases and foundations necessarily of great volume which must be made as light as possible to facilitate transport : such as, tables and beds for printing machinery, large jigs and the like.



By Courtesy of the De Havilland Aircraft Co. Ltd.

Elektron crankcase of Gipsy Six aero-engine.

4. Small non-stressed parts possessing lightness and rigidity, such as: wireless cases, ledger covers, binocular bodies, framework for surgical apparatus etc., etc.

An application which is not included in these categories and is comparatively new to this country, is that of Elektron etching plates. In Germany, Elektron has practically replaced copper and all other materials for this purpose. The use of Elektron here, results in a saving in cost of production and gives excellent results.

Influence of Design

It often happens that a structure or piece of machinery is loaded not only by external forces but by the weight of the structure itself. In particular, where a component, such as a road rammer, is required to withstand shock loads, the latter are increased directly as the weight of the component. The introduction of a magnesium alloy in suitable places here would be beneficial, firstly as the shock loads are decreased and secondly, as the alloy used has good fatigue-resisting qualities. Careful attention should be given to the design of components in magnesium alloys and it is advisable that the designer new to them should make use of the experience of, and execute his designs in conjunction with, those who have been responsible for the development of the alloys. The execution of this practice ensures that the components are not exposed to conditions of design unsuitable to them, and at the same time will ensure that their favourable qualities are exploited to their fullest extent.

The foundryman must be considered when designing cast parts, as the casting processes differ considerably from those of aluminium and have a great influence on the mechanical properties of the finished product.

The alloys are more sensitive to notch effect than those of aluminium and behave in a different manner when in contact with other metals, but these peculiarities can be materially reduced and sometimes turned to advantage by good design. The fire hazards accompanying the machining and use of magnesium alloys in service are negligible. No fire has ever occurred in the latter category which is attributable to the presence of Elektron in the structure. Ignition of Elektron castings, forgings, and sheet over 20 gauge is normally impossible, and for the thinner gauge sheet, practically so, due to its high heat conductivity, and the fact that melting will take place before the ignition point is reached.

Sand and Die-castings

The alloys were originally introduced as castings, and it is in this form in which they are best known in this country. The saving in weight when replacing aluminium alloy castings by those of magnesium alloy, to perform the same duty, is 15–25%; for cast steel 40–50%, and cast iron 50–70%. For components in aluminium and iron not fully stressed, the substitution of cast magnesium alloy may carry a saving of the full difference in the specific weights of the metals.

The Elektron casting alloys are particularly susceptible to heat-treatment and in this condition have ultimate strength up to 19 tons/sq. inch and elongation up to 14%, with Brinell figures up to 60. The most common forms are, of course, sand castings. These give excellent results in the most complicated forms and have a finish of good definition. The quality of castings can be judged by the fact that of 48,501 cast pieces supplied to certain manufacturers, only 417 were rejects, 157 of these being due to errors in machining.

Die-castings in Elektron have been in production in this country for a considerable time and have been very successful. The magnesium alloys here have the important advantage that they have no chemical action with steel.

Elektron pressure die-castings are comparatively new to England, but are now being produced with success for pieces which are subsequently to undergo the minimum of machining. The finish of pressure die-castings is of an extremely high order.

Forgings and Pressings

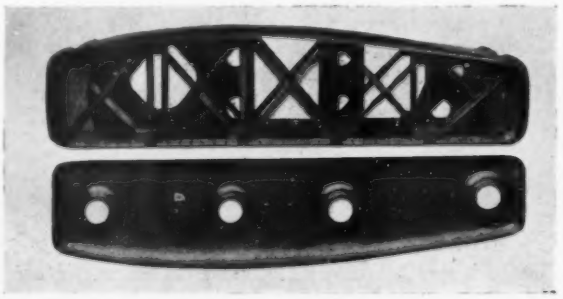
Elektron forging alloys are of great importance to the aircraft and engine designer, and have mechanical properties comparable to those of aluminium alloys, but of two-thirds the weight. In the heat-treated condition the forging alloys now possess ultimate tensile figures of 23 tons/sq. inch, elongation of 16% and are used abroad and in this country increasingly for high-duty components, such as airscrew blades, main aero engine bearers, crankcases, etc., The low modulus of elasticity in comparison with aluminium alloys renders such parts highly resistant to fatigue.

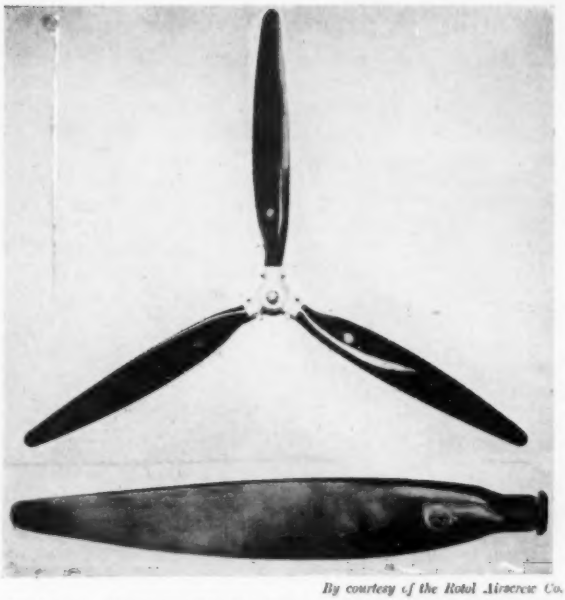
The sheet alloys are now assuming high importance for aircraft work and development in this department has recently been rapid. A process whereby the high strength alloys can be plated with the alloys more resistant to corrosion has recently been successfully developed, giving a sheet of 100% continuity with mechanical properties equal to those of the strongest alloys and corrosion resistance equal to that of the alloys most favourable in this respect. They are utilised by the aircraft engineer in the construction of such parts as petrol and oil tanks, fuselage doors, fairings, cowlings, panelling, etc., etc. The absence of the necessity for heat-treatment after working is an advantage here, and the working itself is a simple operation, due to the ease of deformation of the sheet.

For deep pressings and complicated working, the sheet must be raised to approximately 300° C., but it is hoped shortly to obviate this necessity. Elektron dies for drawing and general presswork on magnesium alloy sheet have recently been found to impart a high perfection of finish to the resulting pressing. The dies have the additional advantage over steel of being easily frazed prior to pressing of the sheet.

Drawn and rolled sections in Elektron can be manufactured from the dies and rolls used for the aluminium alloys, and are employed for moderately stressed members of wing fuselage and tail plane structures, with appreciable

A typical aeroplane wing tank construction in Elektron.





By courtesy of the Rotol Airscrew Co.

Elektron airscrew blades for variable-pitch propellers.

saving in weight. This form is of great importance and it is probable that within the next year or two the structure of all high-performance aircraft will contain a substantial proportion of channel and other structural section in magnesium alloy.

Extruded sections of complicated design are readily produced in magnesium alloys and are used for constructional purposes in the same way as aluminium alloys, having tensile figures up to 22 tons sq. inch and elongation up to 16%. Tubes in certain alloys are extensively used for the manufacture of pilot and passenger seats with welded joints and are highly successful.

Some years ago an aeroplane was constructed in Germany completely of Elektron, using the sheet alloys for all fuselage and wing structure, petrol and oil tanks, etc. The machine was in use under all normal conditions for many years and gave very satisfactory service. The machine was recently dismantled for inspection and showed no evidence of corrosion or any other defect.

Welding Properties

The ease with which Elektron sheet can be welded autogenously, or electrically, is of high importance to the aircraft engineer. The autogenous method for some alloys is as simple as that for steel and gives a finished joint of 98% efficiency.

It is only comparatively recently that resistance welding in the form of spot and seam welds has been brought to a pitch of high efficiency. It is interesting to note that the alloys most conducive to resistance welding are those which are not so favourable for the autogenous method and vice versa.

Electric seam and spot welding for Elektron sheet, are, of course, in the form of lap welds, but the firm of PECO have a process whereby, for the thinner gauges the laps of seam welds may be rolled to produce a flush surface. The welding properties of the Elektron alloys are also valuable for repairing defective or damaged castings, this operation being extremely simple.

Future Trends

Let us now turn to the future of the magnesium alloys. It is obvious that the most important sphere of application will be found in the aircraft industry, where materials of good strength-weight ratio and low specific gravity are essential.

In engines and aircraft themselves, the curve of progress in pure design already shows a flattening tendency which means that with the orthodox principles of design and using the same materials as hitherto, perfection is within sight, and for future progress the designer must seek either a more favourable material or invent a completely new principle for the provision of energy for transport.

Judging by past experience, it is safe to say that the resources offered by all known materials will be completely exploited before the necessity of new principles arrives, and the inference is that the progress made by the aircraft industry in the near future will depend greatly upon the materials available. It is a well-known fact that the Englishman is of a conservative turn of mind; the engineer is no exception and will not willingly incorporate a new material or design which has not been most thoroughly investigated and tested under every condition to which it will be exposed. Whether this tendency is carried to extremes is a moot point but the principle is sound and ensures that the material or design adopted are beyond question thoroughly capable of standing up to their job. The fact that magnesium alloys are now being widely adopted in all industries and the aircraft and automobile trades in particular, has an obvious inference, and it would be no exaggeration to say that the magnesium age has arrived.

Production and Consumption of Tin in 1937.

PRELIMINARY figures for December, 1937, indicate that world production of tin in that month reached an all-time record of approximately 26,000 tons, making the total for the year about 206,000 tons. This figure compares with 180,000 tons in 1936, and exceeds the previous record (of 1929) by 7%. World consumption in 1937, on the basis of the data at present available, is given as 181,500 tons; but it is possible that when fuller information is available the total world consumption for 1937 will prove to be about 194,000 tons.

Consumption by Countries

Tin consumption by the principal countries in the year ended November, 1937, is given in the following table in comparison with the consumption for the preceding year.

Large percentage increases are shown by all the chief tin-consuming countries, with the exception of France, where there was a decrease of nearly 9%. In the U.S.A. there was an increase of about 19%, in the United Kingdom 21%, and in Russia 32%. Substantial increases are also recorded for Germany and Japan, each about 29·5%, and in Canada there was an increase of 16·8% to 2,536 tons.

	Year ended November. 1937. Long Tons.	1936. Long Tons.		Percentage Increase or Decrease.
U.S.A.	85,924	72,273	..	+18·9
United Kingdom	25,383	21,009	..	+20·8
U.S.S.R.	12,600	9,549	..	+32·0
Germany	11,135	8,606	..	+29·4
France	8,937	9,813	..	— 8·9
Japan	8,117	6,266	..	+29·5
Other Countries	29,904	31,684	..	— 5·6
Total Apparent Cons'pt'n	182,000	159,200	..	+14·3

A new table is introduced in a recent issue of the *Bulletin*, showing the tin production of the principal countries for successive twelve-monthly periods, by which the trend in any particular country is at once apparent. Tables of tin production, tin consumption and tinplate production are now presented in much greater detail by countries than formerly, while other new tables give exports of bearing metals and of solder from the United Kingdom and the United States, and indices of consumption of tin, copper, lead and zinc.

The world output of tinplate in 1937 reached a record of 4,020,000 tons, against 3,715,000 tons in 1936. A record was also achieved in the world motor industry, more than 6,300,000 vehicles being produced in 1937, against 5,824,000 in 1936.

New Alloys in Industry

PHYSICAL science is playing a very important part in the development of new materials, a part which was emphasised at a recent Conference of the London Branch of the Institute of Physics. One of the sections discussed concerned the search for new alloys, which Mr. E. A. G. Liddiard of the British Non-Ferrous Metals Research Association stated is continuing to be very largely a matter of trial and error. A known metal is taken and the effect of the addition of various other elements on the properties of the material is determined. Often the results obtained are quite unexpected.

With the increase of metallurgical knowledge, it is possible to suggest various short cuts in the empirical work on new materials. One of the most striking examples of this is concerned with the phenomenon of precipitation or "age" hardening. Mr. Liddiard described this phenomenon as of great technical importance. It deserved the close attention of research physicists and he referred those interested to a paper* by Dr. C. H. Desch. It is largely due to precipitation hardening that aluminium alloys with ultimate tensile strengths up to a maximum of about 33 tons to the sq. in. are now in commercial use. This strength, claimed for a copper-zinc-aluminium alloy, is exactly ten times the strength of super-purity aluminium.

One of the most important new alloys for corrosion-resistance is a nickel-chromium alloy. Aluminium is another example of a film-forming element with a high affinity for oxygen. It is used either as a coating or an alloying element to improve the oxidation resistance of steel and is an important constituent in a number of copper base alloys with good resistance, particularly to corrosion by sea water.

Dealing with powder metallurgy, a technique which had primarily resulted in the reproduction of a range of new materials, Mr. Liddiard referred to a new high density alloy. If tungsten powder is mixed with a small quantity of nickel and copper powder and subjected to considerable pressure and heated above the melting point of copper and nickel, a sintered alloy is obtained with a density of 16·5 gms. per cubic centimetre, which is considerably higher than the density of the heaviest commercial metal lead—11·34 grammes per cubic centimetre. The importance of this new material is its application to radium beam therapy. It has a correspondingly higher absorption coefficient for X-rays and is, therefore, more effective than lead for protection purposes.

Industrial magnesium and its alloys are new materials of considerable importance, particularly in the construction of aircraft. With a specific gravity of 1·736 as compared with 2·72 for aluminium, it is the lightest industrial metal. Its resistance to atmospheric corrosion, though less satisfactory than aluminium, is being improved. Cast magnesium alloys occasionally contain a type of scattered porosity which make them somewhat unreliable, and their strength at high temperatures is low; this disability is also being improved.

Alloy Cast Iron for Moulding Machines

FEW pieces of foundry equipment are required to perform more arduous service than moulding machines, in which the very principle of operation—*viz.*, pressing the sand round the pattern by a series of heavy jolts, involves a demand for good shock-resistance. An alloy cast iron of the following composition has been found to give particularly good service for the jolt piston and upper frame of moulding machines: Total carbon, 3·0—3·1%; silicon, 1·5—1·7%; manganese, 0·8—0·9%; nickel, 0·8—1·0%; chromium, 0·2—0·3%; molybdenum, 0·55—0·7%. This iron has a tensile strength of 25 tons per sq. in., a Brinell hardness of 269, and good machining qualities. It has also a degree of wear resistance which is highly valuable under the abrasive action of the sharp foundry sand.

*Proc. Phys. Soc. Vol. 49, No 274, 1937.

Lithium Discovery in Manitoba

A NEW lithium discovery has been made about 80 miles east of Winnipeg. Four claims have been staked, and stripping of the over-burden has disclosed the vein. It has a width of 60 ft., which has been stripped for approximately 40 ft., and established at a length of 220 ft. A 24-ft. width of practically solid ore was found.

New refining processes, and uses for lithium ores have created a big demand for lithium ores, and while Manitoba has large deposits, these are all too far from a railway to have much commercial significance. Profitable shipments can be made from this property, it is claimed, owing to its closeness to transportion.

Mechanical Properties of Rope Wire in Temperatures ranging from +20°C. to −50°C.

ROPE wires of telpher lines have to work throughout the change of climate during the years in temperatures of very different degrees, especially in mountainous regions. As there are only few investigations to find out how the properties change with the temperature, the authors have carried out detailed tests.

After a short report of the publications on hand, they describe the material tested and the tests themselves. They have investigated the tensile properties and the ability of twisting and of to-and-fro bending of 15 different rope wires, three with low-carbon contents of 0·2 to 0·28%, and tensile strength between 900 and 1,000 lb./sq. in., the others with carbon contents of 0·41 to 0·77%, but divided into two groups, with tensile strength of 1,800 to 2,000 lb./sq. in. and 2,200 to 2,600 lb./sq. in. respectively. One class of wire is investigated in five different steps of drawing, to find out the influence of this operation on the properties of wire. Two of the low-carbon wires contained only traces of silicon and 0·31 and 0·27% of manganese, respectively, while all others contained silicon from 0·13 to 0·20%, and manganese from 0·52 to 0·76%.

The tensile and twisting tests were carried out with one of the 3-ton universal machines of the Losenhausenwerk A.G., combined with a special refrigerating apparatus for producing the low temperatures. A drawing gives the details of this apparatus. For the to-and-fro bending tests a special arrangement is made, and is used in connection with the same cooling apparatus.

The results of the tests are shown in a table which gives the figures of the tensile strength, of the elongation, of the constriction, and of the ability to undergo twisting and to-and-fro bending of all materials investigated at temperatures of −50°, −20°, 0° and +20°C. They may be summarised as follows:

The additional strain produced by shortening the rope wire through refrigeration can be counterbalanced to some extent in all investigated rope wires by the increase of strength at lower temperature. The decrease of the temperature shortens the rope wire about 0·07%—i.e., the load increases about 225 lb./sq. in. The increase of tensile strength is only about 6%, the surety decreases correspondingly. A wire has to be calculated therefore for the lowest temperature possible in practice. The to-and-fro bending and twisting tests have mostly given lower figures at lower temperatures, but this deterioration was essential only at about 20% of the investigated wires, in all other cases without importance. It is, therefore, recommended to carry out tests at low temperatures, if the wire shall be used not only for production of rope wire, but also it is has to sustain additional bending and twisting during later use in practice.

Mitteilungen aus den Kaiser-Wilhelm-Institut für Eisenforschung. Düsseldorf. Vol. XIX. No. 7. Anton Pomp and Alfred Krish. Price, RM.1·50.

Steel Mill Lubrication

By H. N. Bassett, A.I.Mech.E., M.I.P.T.

Good quality lubricants have an important influence on the efficient operation of rolling-mill equipment, and in this article the author discusses the subject in the light of modern practice.

THE development of the automobile and other industries in which steel rolled to certain definite fine limits of accuracy is required has led to more attention being paid to the question of the lubrication of the plant which prepares the steel. In the earlier days the problem was mainly one of protecting moving parts from a certain amount of damage by rust, apart from the natural desire to lower the amount of power lost in the bearings. This called for lubricants with some degree of adhesiveness, capable of resisting pressure and not much affected by temperature variations.

The situation is different to-day, however, because limits are closer and consequently clearances in bearings have to be less, gears must mesh more closely, and more attention is paid to enclosing moving parts to protect them from the adverse conditions under which they generally have to work. Lubrication systems to-day are designed just as carefully as any other part of the plant, and this, with the research which has been undertaken by the oil companies. makes lubrication of steel mill plant a very effective and positive matter.

The bearings to be lubricated which will be considered here are those of rolls, shears, saws and table rollers. In addition, there are many sets of gears and pinions to be looked after, particularly in the bloom mill.

Gears and pinions are nowadays often installed in oil-tight housings, which makes it possible to use a fairly fluid oil and to give bath lubrication. This is very effective, as there is always an ample supply of the lubricant available. Pressure lubrication is also possible under such conditions, the oil being pumped directly on to the teeth at the point of meshing. This is the best method of lubricating gears and pinions, but may be applied only where the housings can be made oil-tight.

Where gears are merely covered with a casing oil-bath lubrication may be impossible, and in such circumstances it is necessary to use a lubricant which is adhesive, and which need be applied only at intervals. Such a method of lubrication is bound to be less positive than either bath or pressure lubrication, more especially as there is always the possibility of the contamination of the lubricant on the teeth by water or by flying particles of grit or scale. A special type of lubricant is required to stand up to these conditions, and either a fairly soft grease or a compounded oil containing a proportion of fatty oil must be used. A straight mineral oil is washed off the teeth by the water.

Where several sets of rolls depend upon one set of pinions it becomes particularly important to avoid wear on the teeth, because if there is any lost motion because of wear by the time motion has been transmitted to the last roll the error due to it will have become appreciable. The lubricant selected, therefore, should be a good one—not likely to break down readily under the pressures involved. (This last statement requires qualification inasmuch as few lubricants, and these not of the type normally employed for steel mill lubrication, will stand up perfectly to high pressures between gears, but what is meant is that only really good lubricants should be used. Cheap ones will fail early and lead to excessive wear.)

Table rollers are driven by means of bevel gears, and these often work entirely exposed. It is impossible to prevent water and scale from finding its way on to them, and they are also exposed to much heat from the metal which is being rolled. The conditions are just about as difficult as they can well be, and effective lubrication is made still more difficult by the fact that any oil used loses much of its viscosity because the gears get so hot, and is therefore thrown off the wheels by centrifugal force. Frequent applications of small quantities of the lubricant must be made : larger ones result in waste, as the excess is simply squeezed out from between the teeth or thrown off. Something of the nature of an almost fluid jelly is required, with a viscosity of (say) 1,800 seconds Redwood at 200° F. Naturally, it should be put on as near as possible to where the teeth mesh, while the gears are running inward.

Lubrication of roll necks is most important and is also very difficult because of the heat which is transmitted from the rolls to the necks, and so to the bearings. Oils are less suitable than greases for this application, for oils become too thin to lubricate effectively. Greases are better also in that they are not so easily displaced by the water which is sometimes fed over roll necks to cool them. The most important property of a roll-neck grease is its melting point, which must be high. The grease must not be carbonised by the heat to which it is exposed, which may vary from 350° to 550° F. The actual grease chosen must be selected according to the working temperature of the necks, as if the melting point of the grease is too high lubrication will be defective. On the other hand, if the grease melts too easily it may run away entirely and fail to function as a lubricant for the greater part of the time. Adhesiveness is a very desirable property which is obtained by special formation : a good roll-neck grease is not made in any haphazard fashion.

Stability is another factor of some importance, as it is usual to collect the grease which melts and flows away from the bearing for use again. The consistency alters gradually, and it may be necessary to mix a proportion of new grease with the old to make it serviceable. Any filler used should not tend to settle out when the grease melts.

Lubrication of shears is a matter mainly of lubricating the motor which drives them and the gears through which the drive is transmitted. The motor requires a fairly light oil of high-quality because the high speed at which it runs tends to fairly high bearing temperatures at which the oil will oxidise and thicken if it has any tendency at all in that direction. As the clearances in the bearings are small such change in the properties of the oil is not at all desirable. The gears are heavily loaded and require an adhesive thick oil or a grease. As they are subject to considerable shock because of the nature of the machine, anything but a good lubricant will fail frequently, permitting metal-to-metal contact between the teeth. This will cause wear, which is not welcome, but which is not so serious a matter as wear in the gears driving stands of rolls. A lubricant similar to that used for roll gears will serve for the gears on shears.

Saws run at high speeds and call for lubricants of high quality. If the housings are oil-tight the problem is simpler than where they are exposed to flying dust, scale, etc., and every endeavour should be made to exclude the possibility of the entry to the bearings of such dust and scale, which is extremely abrasive. A medium viscosity oil is required, again of high quality, because of the

relatively high temperatures at which the bearings work, and of the high speed of the journals. If the journals are fitted with ball- or roller-bearings (as is more common with up-to-date plant) a soft grease is used with which the bearing housing is packed. The bearing then will run for a very long time without attention in a thoroughly satisfactory manner.

Years ago lubrication of steel mill plant was mainly on the unit system—i.e., each bearing received individual attention which varied in regularity and effectiveness according to the accessibility of the bearing. Bearings were exposed, more or less, to the destructive effects of water and dust, and consequently wear was often excessive. Development of design of plant, however, has changed all this, and in modern rolling-mill plant the bearings are protected to the utmost possible extent. Ball- and roller-bearings have taken the place of plain bearings in many cases, and systems of pressure lubrication have been designed to replace the older methods of lubrication.

Pressure lubrication has several outstanding advantages. In the first case, with proper care in application there can be no possible doubt that the lubricant really does get to the points it is meant to lubricate. With other methods of application there may have been doubt at times whether the lubricant got to the working surfaces, and in the case of bearings difficult of access sometimes lubrication was infrequent and often insufficient.

A second advantage is that the system is of necessity a closed one, and hence foreign matter (scale, water, etc.) cannot enter. This is important, because scale is abrasive and leads to rapid and excessive wear. Water also is objectionable because it causes emulsification of the lubricant which is an unsatisfactory state of affairs.

Pressure lubrication is used particularly with greases, and various means of applying the pressure have been tried. There has been a gradual improvement in the design and tightness of bearings, and the use of roller-bearings has been extended as a result of the adoption of this system of lubrication. Greases have tended to become softer, and less power is required for operation of the plant.

Pressure can be applied either manually or by means of compressed air or electrically developed power. For most plants a manually-operated gun will give quite good results, but where long runs of piping are involved something more powerful is required. The manually-operated gun can be used in connection with spring-loaded grease cups by the provision of a filling nozzle on the cup. By watching the plunger of the cup on top, it is easy to see when the cup is full, so the lid need never be removed. No contamination of the grease, therefore, can possibly take place. Grease-cup lubrication suffers from the drawback that the feed is greatest when the cup is first filled, falling off as the cup empties and the spring comes towards the end of its extension. There is one type of spring-loaded grease cup on the market, however, to which this dictum does not apply. Two independently spring-controlled plungers are used, and by this means a uniform rate of flow of the grease is assured.

Collective lubrication from one central point by pipes is preferable to application of the grease by means of cups, as the distribution is more evenly accomplished. It is also easier to clear away old grease and ensure a satisfactory supply of new when the grease is distributed from a central point, under pressure not supplied manually. With the ordinary type of grease gun in which a plunger screws down through a bush in the head a considerable pressure can be developed, but the gun has to be attached to the nipple, which is a messy business. It necessitates also the cleaning of the nipple first, and all this is avoided when centralised lubrication is adopted, mechanically operated.

With mechanically-worked pressure grease lubrication the container may be of considerable size, depending upon the number of points to be lubricated. The pipe-lines normally are at least ¼ in. in diameter, and lines smaller than this are not considered satisfactory.

Lubrication by circulation of fluid oils is not so common, but has been used for gears for steel mills. The oils are fairly heavy, as a rule (about 850 to 1,700 seconds Redwood at 100° F.), and are applied either by means of gravity or under pressure. The former is the more simple, but the latter is the more effective and positive. Temperatures will tend to be lower with pressure lubrication than when oils are gravity, fed, because of the larger amount which is passed through the bearings or the gearbox. Somewhat more fluid oils in consequence can be used for pressure lubrication than will meet the requirements of a gravity system. Attention must be paid to the pour point, naturally, or it may happen that the oil will prove excessively viscous at low temperatures, which will mean a bigger expenditure of power to pump it, and may mean also additional power will be used in the mill.

The possibility of the contamination of the oil by water, etc., must be remembered, and due care taken to filter the oil at some point in the system, so that only clean oil is circulated.

Gears which are not enclosed can also be lubricated with oil under pressure, but a much more viscous oil is needed than that used for other parts of the plant, or much of it may be lost by being thrown off the wheels by centrifugal force. Such wheels should always be covered to prevent a dirty mess being made by splashed oil. The pressure required may be developed by a mechanical attachment to the mill itself, which has the advantage that lubricant is fed to the gears only when the plant is working, or by an independent pump. The latter method has the advantage that lubricant can be fed before the plant starts, so that at no time is the supply of lubricant insufficient. Where the supply depends upon the functioning of the mill itself the teeth will certainly be in contact when first starting, which in time leads to excessive wear. An independently-driven supply is much to be preferred.

Gears can be lubricated also by making use of compressed air applied at intervals, so that a predetermined amount of oil is fed to the rubbing surfaces. It is claimed that heavy oils (viscosity about 1,000 seconds Redwood at 200° F.) can be used successfully when this method is employed.

With modern plants it is more important than it used to be that the lubricants should be of good quality, and this is particularly the case with greases under pressure, and oils used for circulation. Some greases show a tendency to separate into their constituents when put under high pressure, and others have a similar tendency when heated. This is undesirable, as lubrication is thereby rendered defective. Oils used must be of high quality also, possessed of considerable "oiliness," and stable under oxidising conditions, so that they will not gum and form sludge. In view of the possibility of emulsification with water they should possess a good demulsibility factor. Gear oils for exposed gears must have adhesiveness in a high degree, and usually it will be found that they do not demulsify so readily as some others. This is less important, however, than for oils which are circulated.

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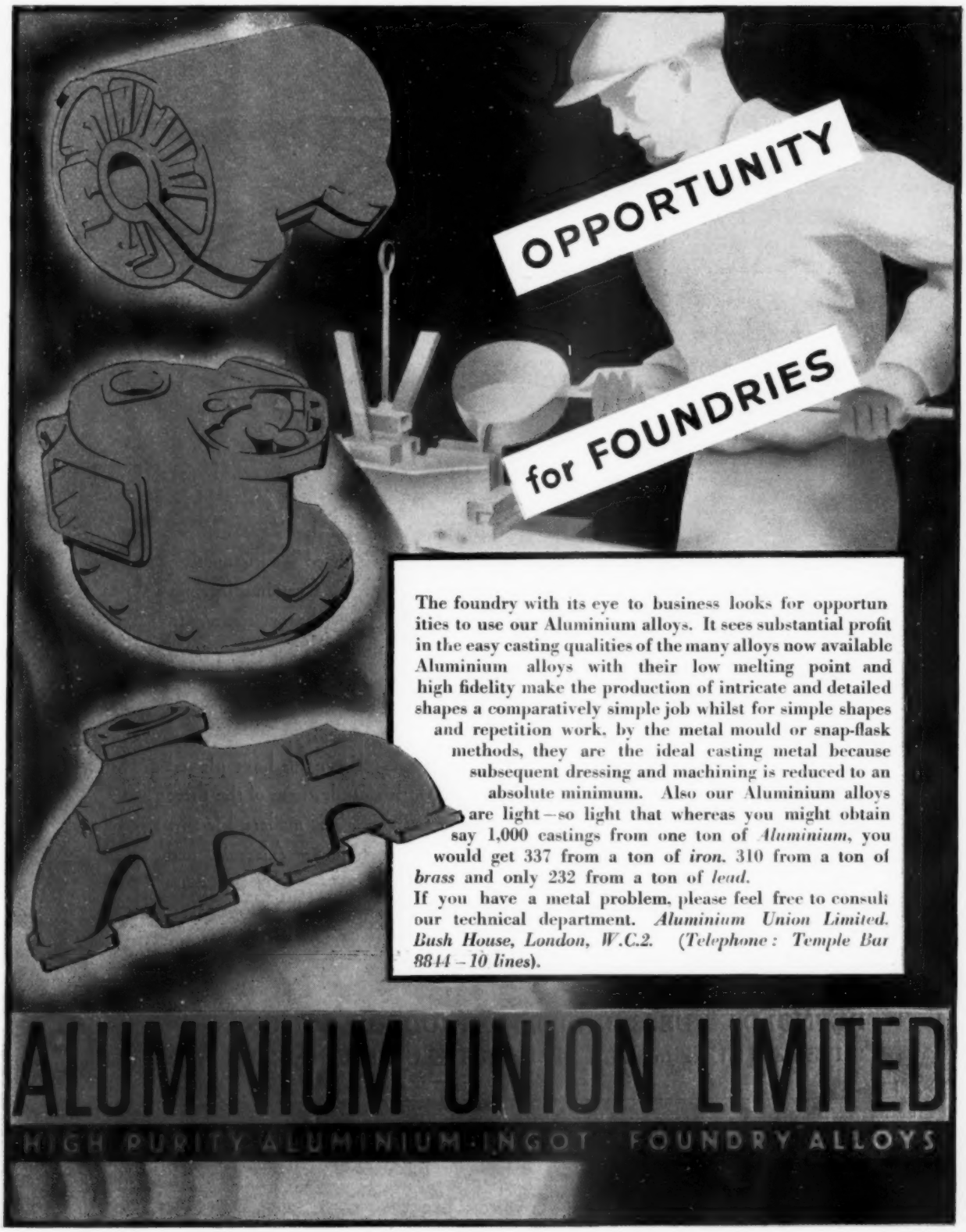
A WORLD REVIEW OF

RESEARCH-DEVELOPMENT-INDUSTRIAL & DOMESTIC USES

February, 1938 METALLURGIA Vol. XVII. No. 100



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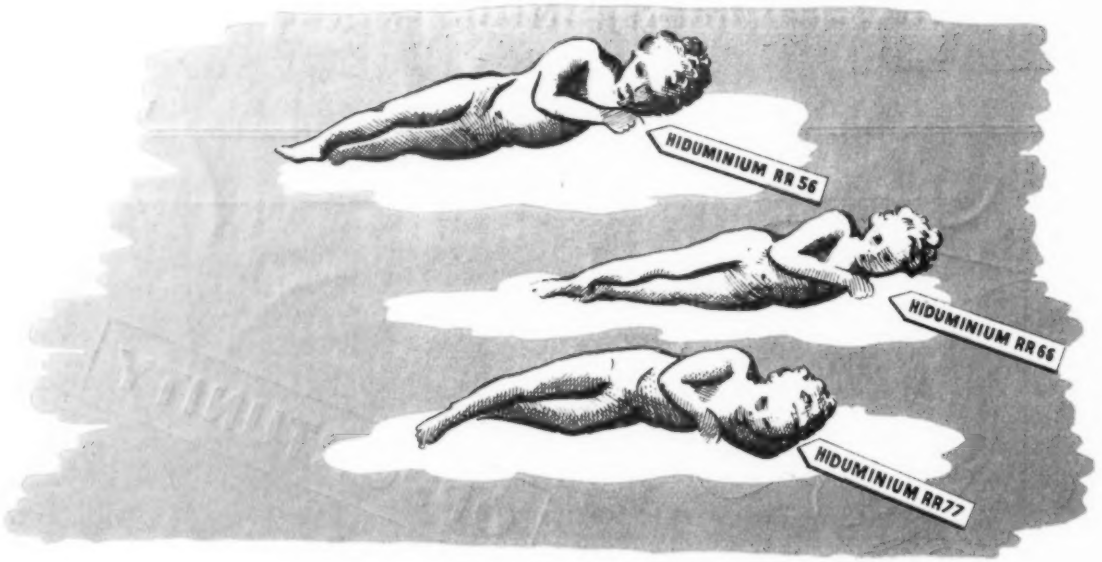

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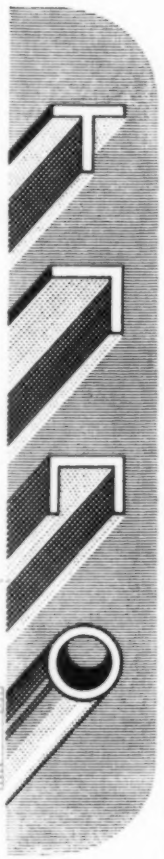

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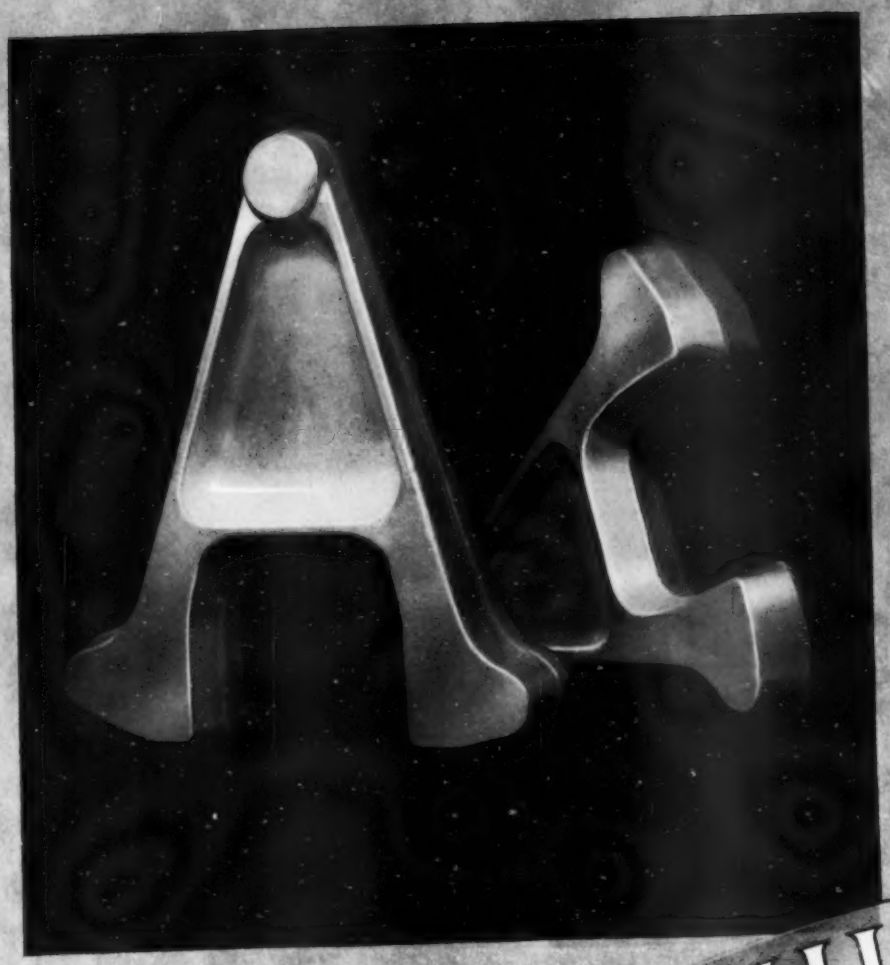

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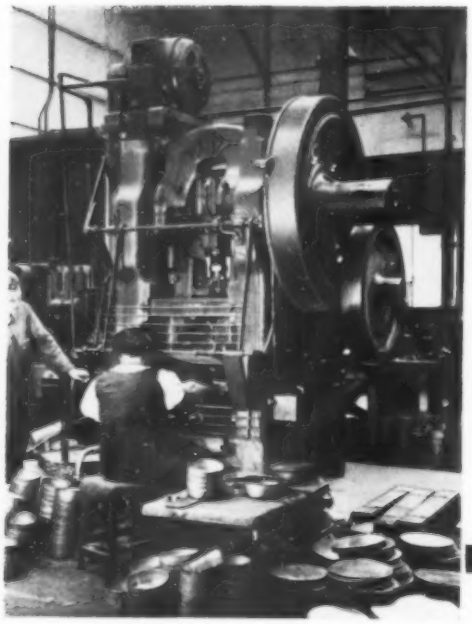

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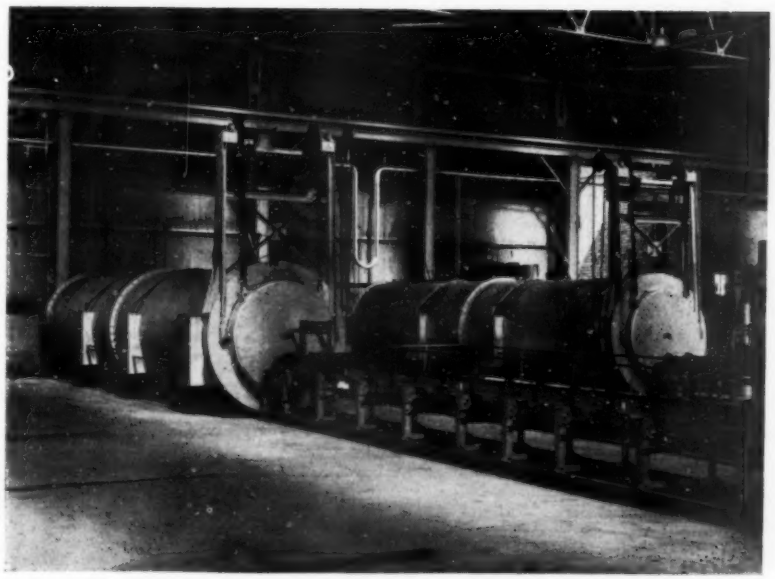

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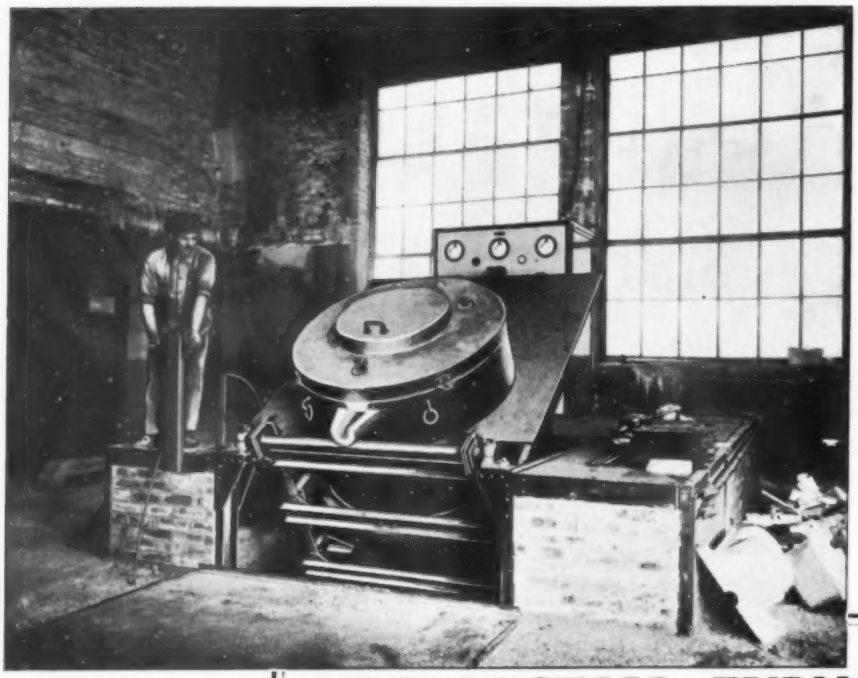

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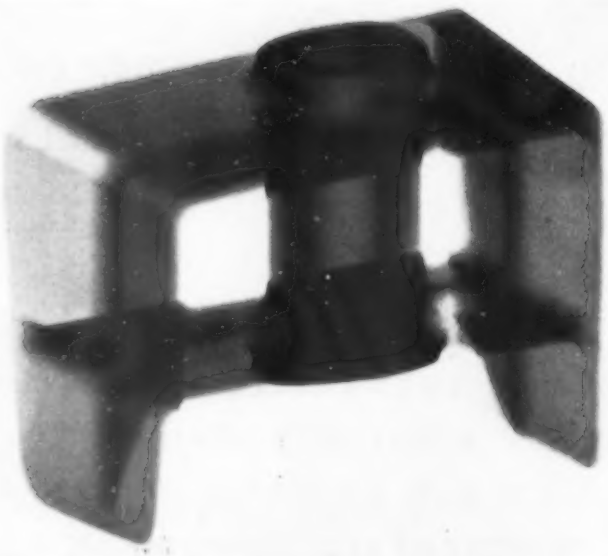

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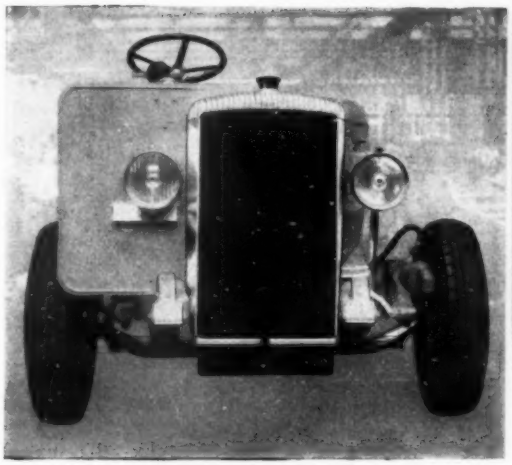

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ALUMINIUM INDUSTRY
A WORLD REVIEW OF
RESEARCH-DEVELOPMENT-INDUSTRIAL & DOMESTIC USES

February, 1938 METALLURGIA Vol. XVII. No. 100

Foreword

By **W. C. Devereux, F.R.Ae.S.**

SIR Humphrey Davey in 1807, although unsuccessful in his attempts to reduce aluminium by heating it with potassium and electrolysing the mixture, gave the elusive metal which he hoped to produce the name of Alumium, which he later changed to Aluminium. The metal was first successfully produced in 1825 by Oersted, whose process was later improved by the great German chemist Wöhler, but it remained a chemical curiosity until 1854 when Sainte-Claire Deville invented a process for its extraction, using metallic sodium in place of the expensive potassium used previously. By this process he was able to reduce the price of aluminium from about £55 per lb. to 11/– per lb., thus, he hoped, making the metal available for commercial use. The concluding words of his book, "De l'Aluminium," published 4 years later, are of interest: "I have tried to show that aluminium may become a useful metal by studying with care its physical and mechanical properties. As to the place it may occupy in our daily life, that will depend on the public's estimation of it and its commercial price. The introduction of a new metal into the usages of man's life is an operation of extreme difficulty." That statement was truly prophetic. Thirty years later, Hall wrote, "The mention of $2 in 1,000 lb. lots doesn't seem to interest anyone . . . they know that the total consumption of aluminium in the U.S. has hardly been 1,000 lb. a year . . . practically no one wanted 1,000 lb."

Mr. W. C. DEVEREUX.

In spite of the pessimistic tone of that letter, Hall, together with his contemporary in Europe, Héroult, had opened up a new era for the aluminium industry by their work on the electrolytic production of aluminium from alumina dissolved with cryolite. By 1905, world production reached 10,000 tons per annum, and in 1936, consumption was estimated at over 400,000 tons, and to-day it is the fifth-ranking metal, with a price stabilised by International Cartel agreement at £100 per ton.

As aluminium became commercially available and was applied to engineering, it became evident that the pure metal was too soft for many engineering processes, and aluminium alloys began to appear. At first, the manufacturers of these alloys met with the same reluctance to adopt these new materials on the part of established industries as had been encountered by the primary aluminium producers, and development was at first slow and tedious, and even to-day there still appears to be a strong opposition among the old-established industries to this relatively new material.

In the early days of its struggle for markets, however, the aluminium alloy industry was particularly fortunate in that the automobile industry was born. This industry, starting with an open mind and a pressing need for light weight and other properties possessed by these new alloys, soon became a substantial customer. It was the coming of the aircraft industry, however, with its essential of ultra-light weight construction for both aircraft and engine which fostered the intensive development which has taken place in the quality of aluminium alloys in recent years.

There is little literature available on the early alloys of aluminium since great secrecy surrounded those which proved most successful. It appears that the most widely used were those containing up to 33% zinc, which probably accounted for many of the fallacies concerning the low corrosion resistance of aluminium alloys. The next developments were the Al-Cu and the Al-Si casting alloys, both types being extensively used in the automobile industry. These alloys, with slight modifications, are still in wide use.

In 1910 there took place a very important step in aluminium alloy progress—Wilm had developed the now world-famous wrought alloy, Duralumin, and, still more important, had discovered the age-hardening phenomenon which had far-reaching effects and gave fresh impetus to the aluminium industry and, incidentally, made possible a great step forward in the aircraft industry.

The next important development took place in England, where, between 1914 and 1919, Rosenhain and his collaborators at the N.P.L. developed the well-known Y-alloy for high-temperature applications and especially for aero-engine pistons and cylinder heads.

These alloys held the field for some time after the War, until about 1927, when in response to increasing demands for higher strength light alloys and, in particular, for the Rolls-Royce "R" Schneider Trophy Engine, Hall and Bradbury, of Rolls-Royce Ltd., developed the now famous series of Hiduminium R.R. high strength cast and wrought alloys. During the last ten years, these alloys have been subjected to intensive development, and together with those of other alloys, such as Duralumin and Y-alloy, the variety of forms in which they are available and their applications, have increased to an enormous extent.

Recently there has been added to this range a new alloy known as Hiduminium R.R.77 which possesses mechanical properties far in excess of any other light alloy commercially available, and which is, on a strength-to-weight basis, superior even to high tensile steel.

Parallel with the development of these alloys great strides have been made in manufacturing technique. Sand-, die- and ingot-casting processes have become highly developed, while on the wrought side, pressing, extrusion, tube-drawing, and rolling of sheet and strip have been

added to the older forging and stamping processes of working high-strength aluminium alloys.

As additional protection against corrosion various methods of plating high tensile alloys with pure aluminium and corrosion-resisting alloys, and the anodic oxidation process, are now widely used and intensive research in this field is progressing.

Among methods of joining aluminium alloys various forms of riveting still hold primary place, but recent developments in electrical resistance welding processes encourage an optimistic outlook for this method of connection.

Of the developments which have taken place in the realms of metallurgical science, much could be written, but suffice it to say that from a minor branch of chemistry, metallurgy has risen, despite its sad neglect in the seats of learning, to a very high position among the industrial sciences, and to-day involves many branches of scientific knowledge and has enlisted to its aid a wide variety of scientific instruments, ranging from machines for testing strength, damping capacity, creep and fatigue resistance, to X-ray diffraction apparatus for the study of the structure of atomic lattice.

Viewed as a whole, the aluminium industry presents a very promising appearance, and in spite of its phenomenally rapid growth it must be considered, when compared with older metal industries, to be in a healthy state of development and there appear to be no insurmountable obstacles in the way of the vast growth which can be foreseen. It may, perhaps, be some time before mechanical properties in excess of those obtainable with existing high-strength alloys are surpassed, but there are considerable opportunities for improvement in respect of properties at elevated temperatures, corrosion resistance, cold working properties, and methods of casting, working and joining.

As regards applications it may be said that most of the metallurgical and engineering development which has so far taken place has been in direct response to the pressing demands of a few industries such as aircraft and automobile manufacturers, and certain of the chemical, food, and electrical industries, and not only are these exacting demands still far from being completely satisfied, but it is felt that we have but touched on the fringe of the vast potential market for aluminium in all its forms which must eventually be opened up as a result of the increasing collaboration which is evident between metallurgical science, engineering practice, and customer.

Raw Materials & Aluminium Production

By William Ashcroft

ALUMINIUM is the metallic base of the mineral, alumina: chemically, it is an element. Unlike most other minerals it is never found native, though it is one of the most plentiful and widely distributed of all substances in combination with other materials. Only oxygen and silicon are more abundant in the earth's crust. Its compounds exist in many forms, from huge masses to rare gems. Clays, slates, shales, schists and the granite rocks are largely composed of aluminium. The oxides of aluminium include corundum, ruby and sapphire; the hydrates gibsite and bauxite; their compounds with magnesium and beryllium; the sulphates occur in many volcanic districts; whilst in combination with the sulphates of the alkali metals it forms the natural alums. The double fluoride of aluminium and sodium—cryolite—is found in Southern Greenland; while the silicates include such diverse materials as the micas, clays, garnets, topaz and the felspars, etc. Many natural waters contain alumina, sometimes in considerable proportion; whilst it is also found in the ashes of plants.

Despite the wide distribution of aluminium, the ore from which the metal is derived is, with few exceptions, the hydrate bauxite, itself containing a decomposition product of silicate, contained in rocks such as granites, basalts, etc. Vast deposits of this mineral, suitable for the extraction of the metal have been located in every continent, and the majority of these are now being worked. The main sources of supply are the states of Arkansas, Georgia and Tennessee, in the United States; Hungary; France; Yugoslavia; British and Dutch Guiana; Netherlands East Indies; Greece being probably the most important, with smaller known supplies, but Ireland, Sweden and India also supply appreciable quantities; other deposits recently worked are located in Mississippi and New South Wales.

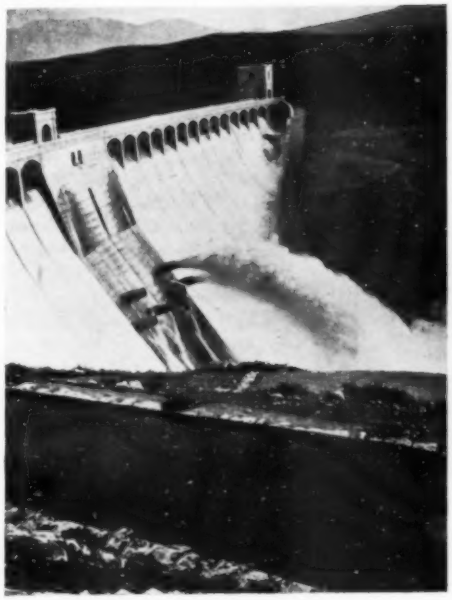
In the production of aluminium, and ranking according to tonnage, the United States and Germany, each with an output of over 100,000 tons during last year, greatly exceed the production of other countries. It is estimated that the U.S.S.R. comes next in importance, with France, Canada, Great Britain, Switzerland, Norway, Italy, Japan, Austria, Sweden and Hungary arranged approximately in order of output.

Courtesy of the North British Aluminium Co. Ltd.

General view of the Lochaber hydro-electric aluminium reduction works.

As a rule, the world's bauxite mines are a considerable distance from the smelting plants, and the ore must be transported near to the source of power. In most countries the refining plants for treating the bauxite are, for natural reasons, placed at some intermediate point between the mines and the smelters. The United States obtains considerable supplies of bauxite from Dutch Guiana, South America; some is obtained from Arkansas and several other States, but the distance of transport to the smelting plants is very great. The major supply of the Canadian aluminium industry is obtained from British Guiana; in this instance the ore is transported 3,500 miles from the mines to the source of electricity.

The smelting plants in the United Kingdom obtain bauxite supplies mainly from Southern France, the ore being shipped to Scotland and Northern Ireland. Norway also receives most of her supplies from France, Italy, and other regions along the Mediterranean coast, where bauxite occurs. For some Norwegian smelting plants the crude ore is refined before shipment. Germany has no bauxite suitable for the production of metallic aluminium, though



Courtesy of the North British Aluminium Co. Ltd.

The Laygan Dam showing two syphons discharging.

A/S Norsk Aluminium Industry's factories at Holmestrand, Norway.

she has extensive deposits of clay, rich in aluminium, near Bantzen, Saxony, for which no economic commercial method of extraction has yet been devised. Her major supplies of bauxite are obtained from Hungary and Yugoslavia, while Italy and the Netherlands East Indies contribute heavily, and, to a lesser degree, France and Greece.

The bauxite deposits in France are probably the largest and richest in the world. In contrast to most other countries she is fortunate in having the mines, and refining and smelting plants situated in adjacent regions, and the ore mined in Southern France is transported a relatively short distance to the aluminium smelting plants in the Alps and in the Pyrenees. The Swiss aluminium industry, like the French, is based mainly on water-power developments in the Alps, and on bauxite supplies from France.

The grade of bauxite is governed by its aluminium-oxide content, and by the impurities present. Normally, it should contain from 55 to 60% of alumina, while high-grade ores, such as those of British Guiana, may contain 61 to 62%. The principal impurities are iron oxide and silica. Most European ores are of the dark-red, high-iron variety; whereas those mined in tropical and sub-tropical regions are very much lighter in colour, from grey to pink, and relatively low in iron content. Thus, the iron oxide present may vary from 25% to about 2%. There is no particular disadvantage in the presence of iron, apart from the fact that it must be handled in the refining process.

A number of other materials are necessary in aluminium manufacture, among which are sodium carbonate and lime for refining the ore, and coal, fuel oil, or gas for calcining the refined ore; in addition, cryolite, either natural or artificial, is indispensable in the present commercial production of the metal, as also is carbon for the electrodes. The smelting of the alumina necessitates a substantial supply of electricity, and for economical production it must be cheap; for this reason water power is generally applied to the generation of electricity. In exceptional cases, however, steam is used for generating electricity, when adequate supplies of cheap coal are at hand.

The European bauxite is, as a rule, transported direct to the refining plants without preliminary treatment at the mines. In North and South America, however, a certain amount of treatment is given to the ore before it is transported, for economical reasons. The bauxite, direct from the mines, is crushed to a suitable size, washed to remove as much earthy matter as possible, and, subsequently, dried in rotary kilns to remove most of the free moisture, which in the crude bauxite amounts to about 12 to 15%. In the crushed and dried form it is transported to the ore-refining plants, which are generally reasonably near to the smelting plants. The moisture content of European bauxites is much lower, rarely exceeding 8%, and the need for drying before transportation is not so important.

The production of high-purity aluminium is only possible from high-grade raw materials, and commercially it cannot be obtained direct from the ore. The various impurities of bauxite must be removed to leave aluminium oxide as nearly chemically pure as possible, and this involves very complicated treatment. It is the conversion of the ore into pure aluminium oxide which is so important in the production of aluminium because the process is relatively expensive. Highly refined aluminium oxide, or alumina, as it is generally known, will contain small percentages of the oxides of iron, silicon and titanium, and, since high purity is aimed at in the final production of the aluminium, commercial alumina must be free from these oxides.

Several processes of treating bauxite to produce alumina are in industrial operation. Of these the most important is the Bayer process, invented by K. J. Bayer over 50 years ago. This process is employed for the greater part of the world's production of alumina, especially for those bauxites which are relatively low in silica. In this process the crushed and dried bauxite is treated with a strong solution of caustic soda, under pressure, at a temperature of about 150° C. This causes the aluminium oxide content in the bauxite to pass into solution as soluble sodium aluminate, and is separated from the insoluble-contents, comprising principally iron oxide and sodium

General View of Laygan Dam.

Courtesy of the North British Aluminium Co., Ltd.

aluminium-silicate. The solution of sodium aluminate is diluted and treated with aluminium hydrate, and, by stirring, about two-thirds of the alumina content is precipitated as aluminium hydrate, which is separated from the solution. The solution itself is concentrated and used over again in the treatment of the bauxite. The aluminium hydrate is calcined at a temperature of 1,100° C. in a rotary furnace to produce alumina ready for electrolysis.

When the silica content of bauxite is relatively high this process is uneconomical, because each pound of silica in the ore involves a loss of about 1½ lb. of alumina and 2 lb. of soda in the silicate formed; for this reason the Bayer process is not generally used when the silica content of the bauxite to be treated exceeds 5%; as a rule those with less than 3% are preferred for this process.

Another relatively old process is the lime-soda process, from Le Chatelier's patent. In this the bauxite, together with lime and soda ash, are sintered and treated with water or alkaline solutions to form a solution of sodium aluminate, as in the Bayer process. The solution is treated with flue gases containing carbonic acid, and aluminium hydrate is precipitated. The soda is recovered from the solution and used over again in the sintering process.

A more recent process to be operated with success is the Paterson process, which has been employed for a number of years at the works of Norsk Aluminium Company at Hoyanger, Norway. In this process the bauxite is smelted direct, with limestone and coke in large electric furnaces. A slag is formed from which the alumina is recovered as aluminate of lime; at the same time the iron content of the bauxite is run off into pig iron. The slag is crushed and treated with soda solution, and, as in other processes, a solution of sodium aluminate is formed which, on being treated with flue gases, precipitates aluminium hydrate. The hydrate is separated from the solution and calcined.

The reduction of the alumina is effected by electrolysis. The furnace used for the purpose is usually a large, rectangular steel receptacle lined with suitable refractory bricks, and carrying an inner lining of an electrically conductive carbon composition, forming a hearth on which the alumina is decomposed. Below the carbon lining are placed cast-iron or steel contact bars of suitable size: these must be in good electrical connection with the carbon hearth, which forms the cathode of the operation. Electrolysis takes place at a temperature of about 930° C., at which temperature the melt comprises a solution of alumina in molten cryolite. The anode consists of a number of carbon electrodes in direct contact with the electrolyte.

The cryolite, which is of lower density when molten than aluminium, becomes saturated with alumina, and aluminium separates out and sinks to the bottom of the container, from which it is tapped through a tapping spout in the side. Cryolite is an essential raw material, and whether a natural or synthetic material is used, it is necessary that it should be free from impurities. The material is a double fluoride of aluminium and sodium, and a typical electrolyte for the reduction of alumina consists of 36% cryolite, 44% aluminium fluoride, and 20% fluorspar. Although the bath is not decomposed by the electric current unless the voltage is excessively high, there is a constant loss of fluorine due to volatilisation and also to the formation of incrustations on the lining; it is necessary, therefore, to make up for the deficiency to the bath.

Under normal operations the consumption of the different raw materials in the electrolytic process per 100 lb. of aluminium produced may be roughly taken as 200 lb. of alumina, 60 lb. of carbon anodes, and about 5 to 10 lb. of cryolite. The consumption of electric power is about 10-kw. hours per lb. The consumption of the carbon anodes is noteworthy. In many modern plants the recently developed self-baking Söderberg electrode is used, but carbon electrodes are in more general use. These carbon electrodes must have high electric conductivity and a low rate of burning over the electrolytic bath. They consist of pure petroleum coke, pitch coke, or ordinary coke, with very low ash and volatile matter content, which is crushed and mixed with pitch or tar and compressed into rectangular blocks, which are baked in special furnaces.

The raw metal from the electrolytic process is cast into pig ingots, which are remelted in electric or reverberatory furnaces in order to remove dissolved gases, sodium and other impurities. During this refining process small percentages of alloying elements may be added according to the requirements of the various products. The refined metal, or alloy is poured into permanent moulds to form rolling slabs, ingots, wire bars or billets for extrusion.

Empire Production

The United Kingdom and Canada are the only producers of aluminium from its ore in the British Empire, but there are important manufacturing aluminium industries in India, Australia, South Africa and New Zealand. Early developments in production in this country were made by the British Aluminium Co., Ltd. in 1894. Hydro-electric works were erected at Foyers, Inverness-shire, which enabled the company to pioneer the development of the aluminium industry in this country. The ore used was from Northern Ireland, and it was treated by the Bayer wet process.

As the demand for aluminium grew the company erected a new hydro-electric station for production at Kinlochleven, Argyllshire. The need for still further production led the company to initiate the formation of the Lochaber Power Company in 1921, which obtained statutory powers for the development of the Lochaber Water Power Scheme, which will ultimately result in the development of 100,000 h.p.

The British Aluminium Co. Ltd. is by far the largest producer of aluminium in the United Kingdom with reduction works at Foyers, Kinlochleven and Lochaber, which are supplied with alumina from the works at Larne and Burntisland. These works in turn are supplied with bauxite from the company's own mines in southern France and in British Colonies.

The Aluminium Corporation is another producer of aluminium in the United Kingdom. The alumina is produced at works situated at Hebburn-on-Tyne, which is reduced to aluminium at Dolgarrog, North Wales.

Although Canada's mineral resources are rich and varied, bauxite has not yet been discovered in workable quantities, but she is well supplied with other materials used in the production of aluminium, together with cheap and abundant water-power. It is not surprising therefore, that an aluminium industry has been established in Canada for many years. The construction of an aluminium smelter was, in fact, started as long ago as 1899 by the Northern Aluminium Co. Ltd., which became the Aluminium Company of Canada Ltd. in 1925. This was one of the first industries to locate at Shawinigan Falls, Quebec, and the first aluminium ingot was produced two years later.

The aluminium oxide used for reduction to metal was, until recently, prepared in the United States, but in 1936 the Aluminium Company of Canada Ltd. brought into operation the Arvida plant, at which four electric furnaces are installed for the production of aluminium oxide from calcined ores, and now calcined bauxite is supplied direct from British Guiana. Many of the deposits in this ore field are owned by the Demerara Bauxite Co. Ltd., an associated company of the Aluminium Company of Canada Ltd., which, with raw materials and manufacturing facilities, provides a self-contained aluminium industry.

Until a comparatively few years ago, practically all the world's markets were open to Canadian aluminium: to-day many of these markets are closed. Since the conclusion of the Ottawa agreements, however, exports to countries of the British Empire have increased rapidly and recent figures show the export of aluminium bars, blocks, etc., reached 45,500 tons in 1937, an increase of about 12,000 tons on 1936.

Recent Developments in the Metallurgy of Aluminium and its Alloys

By

G. A. ANDERSON, B.A.

The metallurgical possibilities of aluminium and its alloys have been developed to such an extent during the last twenty years that radical improvements can only be expected at infrequent intervals; these developments are discussed, and attention directed to the present trend of research for improved alloys for application to special purposes.

THE aluminium industry, now just past its fiftieth year of serious commercial activity, owes a very large part of its phenomenal expansion to the remarkable effects on mechanical properties of alloying the pure metal with other elements; the number of such alloys now runs into thousands and the position must seem rather bewildering to a very large number of present and potential users. The issue of specifications for individual materials by responsible bodies such as the British Standards Institution and the Air Ministry offers the user a ready means of assuring quality but only gives guidance as to choice of material so long as the total number of specifications is comparatively small. Progress in the alloy field has, however, been so rapid that new specifications have had to be added constantly until the total number is now so great that the guidance factor has entirely disappeared.

In Germany, where the industry has embarked on tremendous expansion as part of the political drive for self-sufficiency, a system of alloy classification based on chemical composition has been adopted that enables users to specify the alloy type required while still leaving room for competitive variations of the type. The main classification headings are chosen so that alloys of any one family have general characteristics in common, such as response to heat-treatment or resistance to corrosion, and these characteristics are detailed on each specification. In this country official approval has not yet been given to any comprehensive system of classification, but the tendency is to try and fit new materials into existing specifications and to make new specifications broad enough to cover alloy types rather than individual proprietary brands; in this way the materials of general interest to engineers are being sorted into fairly definite classifications and it may be of assistance to review these, as far as possible in order of ascending mechanical properties, in a series of tables that may serve for record purposes.

TABLE I.

PURE ALUMINIUM—WORK-HARDENED.

Temper.	Tensile Range, Tons/sq. in.	Average Properties for 16—24 s.w.g.			
		0·1% Proof Stress, Tons/sq. in.	Elongation % in 2 in.	Brinell Hardness.	Bend Test.
Soft	5·0—6·5	1·3	40	22	Sheets will withstand 180° flat bend
¼-Hard	6·0—7·5	5·6	14	31	180° flat bend
½-Hard	7·0—8·5	6·6	9	35	180° over $r = \frac{1}{2}\ t$
¾-Hard	8·25—9·75	7·4	6	38	180° over $r = \frac{1}{2}\ t$
Hard	9·25 min.	8·1	6	41	180° over $r = t$

Note.—Soft, ¼-Hard, and Hard, tempers satisfy, respectively, B.S. Specifications 2.L.17, 2.L.16, and 2.L.4.

Pure Aluminium

TABLE I.

An essential step towards general standardisation has been agreement between the principal producers as to the properties of commercial quality sheet and strip. The specified minimum purity of the commercial grade is 98%, but actually the great majority of it is appreciably over 99%. Five tempers of sheet have been found necessary because of the enormous variety of manufacturing operations for which this material is employed; the mechanical properties are based on ranges of tensile strength for each temper, these ranges and average figures for other corresponding mechanical properties are given in the accompanying table.

In addition to the commercial grade there are available a 99·5% minimum grade, which is generally used for chemical plant, and still higher purities for special purposes, up to 99·8% minimum. Electrolytically refined aluminium is now also in commercial production under the name Super Purity Metal and has been standardised at 99·99% minimum purity. With such extremely high purity there are naturally certain difficulties in producing semi-manufactured forms, and still more so fabricated plant, free from contamination, and it may be that a little time must elapse before the necessary technique has been perfected; it is certainly too early to be able to assess the true commercial significance of this very interesting material.

Alloys for General Engineering Purposes

In the following tables a system of primary and secondary classification has been adopted, that perhaps needs some explanation; in the main headings are included the elements that primarily determine the characteristics of the types, while in the secondary headings are those that, although having a definite influence on properties, do not alter them sufficiently radically to warrant separate classification; these secondary additions are not always present in every commercial variation of the type and generally do not exceed 1·0 to 1·5%. Wrought alloys have been considered separately from cast, and each sub-divided into those that are commercially heat-treated and those that are not. In order to keep the picture as simple as possible, wrought alloys have been considered in sheet form only; in the case of those that are work-hardened, only soft and hard tempers have been included although one or more intermediate ones may also be in existence. In addition, extruded sections are in most cases available having properties equivalent to soft temper, also tube and wire having properties ranging from soft to hard. In the case of heat-treated materials, sections, tubes, and forgings are generally available with properties very similar to those of the sheet.

Wrought Alloys—Work-Hardened

TABLE II.

The increased use of stress-bearing panels in designs for both land and air transport has created a demand for light sheet materials stronger than pure aluminium but

TABLE II.
WROUGHT ALLOYS—WORK-HARDENED.

Type.	Major Constituents. (Balance Al.)			Temper.	Min. Mech. Properties.			Commercial Designation.
	Mg.	Mn.	Si.		U.T.S. Tons sq. in.	0·1% P.S. Tons sq. in.	Elongation % in 2 in.	
Al Mn	—	Up to 1·5	—	Soft	6·5	—	30	BA 60 A
				Hard	13·0	11·0	3	D.T.D.213
Al Si	—	—	11·0	Soft	9·0	—	20	BA 40 D
				Hard	12·0	10·0	5	
Al Mg Mn	Up to 3·0	Up to 1·5	—	Soft	11·0	—	18	BA 20
				Hard	16·0	14·0	5	D.2 Birmabright II D.T.D.209a 249
Plus Fe, Cu, Ni	3·0—6·0	Up to 0·75	—	Soft	14·0	—	20	Birmabright
				Hard	20·0	15·0	3	RR.66 D.T.D.180a 170a
	6·5—10·0	Up to 0·6	—	Soft	20·0	—	20	M.G.7
				Hard	25·0	17·0	15	D.T.D.182a 177a

able to withstand drastic forming operations, such as panel-stretching. For the most highly-stressed components heat-treatable alloys may be essential, but they must generally be worked in the annealed condition and finally heat-treated: for secondary work the medium strength alloys in the appropriate temper offer just the combination of properties required for forming without the complication and expense of heat-treatment.

The aluminium-manganese alloy has 30 to 40% greater strength than pure aluminium in the corresponding temper and yet is practically as ductile. It is also less easily softened by exposure to temperatures up to 250° C. It is very little more expensive than the pure metal and, like the latter, is available in five standard tempers.

The aluminium-silicon alloy has rather better mechanical properties in the softer tempers and this, coupled with other characteristics such as freedom from hot shortness, makes it very suitable for welded construction.

The aluminium-magnesium alloys, with minor additions of manganese, offer considerable improvements in mechanical properties with increasing magnesium content. Alloys containing up to about 4% magnesium are well adapted to deep drawing and pressing, and are being increasingly used where something stronger than the aluminium-manganese alloy is required. Their strength and rigidity in the annealed condition makes them particularly attractive for welding, but they are rather less simple to weld than the two other types, especially when the magnesium content exceeds about 5%. The resulting joint, however, retains a higher proportion of the original strength of the material than with other alloys, especially those that derive their strength from heat-treatment.

All three types can be considered generally as equal to pure aluminium in respect of corrosion resistance, while the magnesium series is particularly suitable for withstanding marine conditions.

Wrought Alloys—Heat-Treated

TABLE III

The discovery of the age hardening phenomenon by Wilm just over 30 years ago was the starting point from which our present knowledge of the art of heat-treatment has been derived and the modern range of heat-treated aluminium alloys can all be said to bear some relationship to the original Duralumin.

TABLE III.
WROUGHT ALLOYS—HEAT-TREATED.

Type.	Major Constituents. (Balance Al.)							Min. Mech. Properties.			Commercial Designation.
	Cu.	Mg.	Mn.	Ni.	Zn.	Si.	Fe.	U.T.S. Tons sq. in.	0·1% P.S. Tons sq. in.	Elongation % in 2 in.	
Solution treated (480° to 520° C.) and aged at room temperature.											
Al Mg Si Plus Mn	—	Up to 1·25	Up to 1·0	—	—	Up to 1·25	—	16·0	10·0	20	Duralumin H
Al Cu Mg Plus Mn	4·0	0·6	0·6	—	—	—	—	25·0	15·0	15	Duralumin B 5.L.1
	4·0	1·3	0·9	—	—	—	—	28·0	17·5	15	Duralumin G D.T.D.270
Al Cu Ni Mg	4·0	1·5	—	2·0	—	—	—	23·0	14·0	15	"Y" Alloy B.S.S.414
Solution treated (450° to 520° C.) and precipitation treated (120° to 175° C.)											
Al Mg Si Plus Mn	as above							20·0	16·0	10	Duralumin H
Al Cu Ni Mg Plus Fe, Si, Ti	2·0	0·8	—	1·3	—	0·6	1·2	27·0	21·0	10	RR.56 D.T.D.206
Al Zn Mg Cu Plus Ni	2·2	3·0	—	Up to 1·0	5·0	—	—	33·0	27·0	8	RR.77

TABLE IV.

CAST ALLOYS—NOT HEAT-TREATED.

Type.	Major Constituents. (Balance Al.)						Min. Mech. Properties.						Commercial Designation.
							U.T.S. Tons/sq. in.		0·1% P.S. Tons/sq. in.		Elongation % in 2 in.		
	Cu.	Mg.	Mn.	Ni.	Zn.	Si.	Sand.	Die.	Sand.	Die.	Sand.	Die.	
Al/Cu	7·0	—	—	—	—	—	7·5	9·0	3·5	3·5	1·5	3·0	4.L.11
	12·0	—	—	—	—	—	7·0	9·0	4·5	4·5	—	—	3.L.8
Al/Zn/Cu	2·75	—	—	—	13·5	—	9·0	11·0	3·5	3·5	2·0	3·0	3.L.5
Al/Si (mod.)	—	—	—	—	—	12·0	10·5	13·0	3·5	4·5	5·0	8·0	Alpax L.33
Al/Mg/Mn	—	3·0 to 6·0	0·25 to 0·75	—	—	—	9·0	11·0	5·0	5·0	3·0	5·0	Birmabright D.T.D.165
Al/Cu/Ni/Mg	4·0	1·5	—	2·0	—	—	10·0	12·0	8·5	8·5	—	—	"Y" Alloy 2.L.24

Duralumin, sometimes with rather higher manganese and magnesium contents than in the original composition, is still the most widely used strong alloy for general purposes. The value of nickel additions for improving strength at high temperatures was first demonstrated by work done at the National Physical Laboratory, culminating in the development of "Y" alloy.[1] The next important step was the addition of iron and silicon, as in RR.56, to give alloys requiring precipitation treatment but having still better mechanical properties. The beneficial effect of precipitation treatment is particularly noticeable in the elastic properties, but there is, on the other hand, an appreciable decrease in ductility.

The addition of the aluminium-zinc-magnesium-copper type represents one of the outstanding developments of the past twelve months. The excellent mechanical properties of such alloys were, as in the case of "Y" alloy, first demonstrated by work done at the National Physical Laboratory nearly twenty years ago, but their shortcomings in respect of ease of working and stability then seemed to be against their successful exploitation commercially. The new alloy, containing a very much lower percentage of zinc, seems to have overcome these disadvantages and provides a very substantial improvement in mechanical properties over the previous strongest materials.

The alloys that age at room temperatures have better corrosion resistance than those that are precipitation treated but the availability of anodic treatment has made this of little practical importance where the additional expense can be afforded. Protection is also regularly provided for sheet by a very thin coating of high purity aluminium rolled or cast on at an early stage during manufacture, means for providing tubes and sections with a similar coating have not yet been perfected, but research work is in hand which, if successful, will be of the greatest importance commercially.

Had it not been for the development of these methods for protection very much more interest would have been taken in the aluminium-magnesium-silicon alloys, for their corrosion resistance, particularly in the solution treated condition, is outstanding. They are more highly developed in Europe and America, particularly with additions of antimony, which still further enhances resistance to marine conditions. This type of alloy is unique in having an electrical conductivity approaching that of pure aluminium and this property has led to its adoption for certain types of overhead conductor in place of the more common steel-cored aluminium.

Cast Alloys—Not Heat-Treated

TABLE IV.

Although recent research has largely been centred on the heat-treated alloys, it is still the fact that the majority of castings for general engineering purposes are made in alloys from one or other of the first three groups.

The "modification" process for aluminium-silicon alloys, except the heat-treated varieties, is now free from patent restrictions and they will probably enjoy an even wider popularity in spite of the necessity for rather more accurate control in the foundry. Their excellent casting qualities, combined with their corrosion resistance, make them particularly suitable for chemical engineering. Their ductility, either sand- or die-cast, is exceptional, but their elastic properties are inferior.

Casting alloys containing up to about 6% magnesium are being used increasingly for architectural and other applications where ability to take a high polish and to withstand handling without discolouration are essential. They are particularly suitable for decorative anodic treatment in cases where castings and wrought materials are combined, the film being a close match to that obtained on pure aluminium and a number of wrought alloys.

"Y" alloy has by far the best elastic properties; its ductility is negligible, but for many types of castings where the maximum rigidity is required, this is of relatively little importance.

Cast Alloys—Heat-Treated

TABLE V.

It will be seen that there are three types of heat-treatment practised commercially: precipitation treatment, or "Tempering,"; solution treatment, involving quenching and a measure of ageing at room temperatures depending on the alloy composition; and, finally, full heat-treatment consisting of solution treatment, quenching and precipitation treatment. Precipitation treatment at low temperatures avoids any risk of distortion, but depends for its effectiveness on the degree of chilling in the mould during the manufacture of the casting. The increase in tensile strength over "as cast" material is not great, amounting to some 5%, but the improvement in elastic properties is much more marked and is of the order of 40%. This treatment is particularly valuable for intricate castings, as it also serves to relieve internal stresses set up during solidification and contraction. Solution treatment gives a very useful combination of strength and ductility, it should also be noted that the alloys in this state are in the best condition to withstand corrosion. The addition of a precipitation treatment brings about a substantial improvement in the elastic properties but at the expense of most of the ductility.

The introduction of about 0·1% of a grain refining element, such as titanium, helps to ensure uniform properties and improves the response to heat treatment; recently, cerium, chromium and columbium have been brought forward as alternatives. The alloy containing cadmium is a rather interesting one, combining strength with more than usual ductility and exceptionally good machining qualities. It is further claimed to have valuable non-seizing properties when in working contact with iron or bronze under corrosive conditions.

The 10% magnesium alloy is a comparative newcomer to this country, although it has long been popular in America and on the Continent. With more than about 7% magnesium, a rather special foundry technique is

[1] Inst Mech E, 11th Report, Alloys Research Committee.

TABLE V.

CAST ALLOYS—HEAT-TREATED.

Type.	Major Constituents. (Balance Al.)							Min. Mech. Properties. U.T.S. Tons/sq. in.		0·1% P.S. Tons/sq. in.		Elongation % in 2 in.		Commercial Designation.
	Cu.	Mg.	Mn.	Ni.	Si.	Fe.	Cd.	Sand.	Die.	Sand.	Die.	Sand.	Die.	
Precipitation treated 150° to 175° C.														
Al/Si/Mg Plus Mn	—	Up to 0·6	Up to 0·6	—	12·0	—	—	11·0	15·0	6·0	8·5	1·5	3·0	Alpax Beta D.T.D.240
Al/Cu/Ni/Mg Plus Fe, Si, Ti	1·3	0·1	—	0·9	2·25	1·2	—	11·0	12·5	7·5	8·0	2·5	4·0	RR.50 D.T.D.133B
Solution treated 425° to 535° C.														
Al/Cu/Ni/Mg	4·0	1·5	—	2·0	—	—	—	14·0	18·0	13·0	14·0	—	2·0	"Y" Alloy L.35
Plus Fe, Si, Ce	2·5	0·75	—	1·5	1·2	1·2	—	14·0	20·0	11·5	13·0	—	5·0	Ceralumin D D.T.D.250
Al/Cu/Cd/Mg Plus Mn, Si, Ti	3·25	0·8	Up to 0·5	—	Up to 2·5	—	1·5	14·0	17·0	11·0	12·0	3·0	5·0	Aeral A/H D.T.D.294
Al/Mg	—	10·0	—	—	—	—	—	16·0	18·0	11·0	13·0	7·0	12·0	BA/29 D.T.D.300
Solution and precipitation treated.														
Al/Si/Mg Plus Mn	as above							15·5	19·0	13·0	16·0	—	—	Alpax Gamma D.T.D.245
Al/Cu/Ni/Mg Plus Fe, Si, Ti	1·2	0·5	—	0·8	2·5	1·1	—	19·0	22·0	18·0	19·0	—	—	RR.53C D.T.D.389
Plus Fe, Si, Ce	2·5	0·75	—	1·5	1·2	1·2	—	18·0	23·5	17·5	20·0	—	—	Ceralumin C D.T.D.255

advisable, comprising the use of flux covers and additions to the moulding sand designed to prevent oxidation, but with these precautions, the combination of strength and toughness obtained after solution treatment at about 430° C. is exceptional. This, coupled with its excellent corrosion resistance, makes the alloy particularly suitable for heavy duty applications, and it has, for instance, been used with success for components of the buckets for mechanical excavators.

Alloys for Specific Purposes

From the foregoing it can be seen that the demand for light and strong materials for general engineering purposes is very fully provided for. Any new material, to be successful, must show definite advantages in respect of mechanical properties, ease of working, or corrosion resistance, and it can be said that the metallurgical possibilities have been so fully explored during the last twenty years that radical improvements can now only be expected at rather infrequent intervals. Research has, therefore, largely been directed towards producing improved alloys for specific purposes such as for use at high temperatures, for bearings, or for machining on automatic lathes; such alloys do not easily fit into any general classification and they are best considered separately.

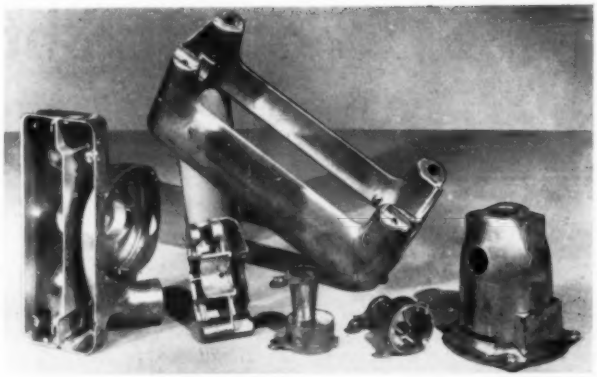
Alloys for Use at Elevated Temperatures

Without the thermal and mechanical advantages of light alloy construction, the internal combustion engine would not have been able to reach its present pitch of efficiency; this applies particularly to the piston. Three types of alloy are in general use for pistons: a 10% copper alloy with additions of iron and magnesium, copper-nickel-magnesium alloys such as "Y" alloy and RR.53, and a 12% silicon alloy with additions of nickel, copper and magnesium. They are generally die-cast, but the last two types may, with slight modification, also be used for forged pistons, which are popular for aircraft and other highly-stressed designs. The coefficient of expansion of the silicon alloy is ·000019 per °C. as compared with ·000022 for the other two, but at the temperatures at which the load-bearing portions of a piston operate the difference is not sufficient to affect clearances to any great extent. Pistons are in almost all cases heat-treated, because, although the centre of the crown becomes fully annealed, the skirt and gudgeon pin bosses derive permanent benefit. Whereas formerly the accepted practice was to give solution and precipitation treatment designed to develop a Brinell hardness of 130 to 150, it is now generally recognised that it is better to give a final stabilising treatment at about 200° C. in order to relieve internal stresses and to ensure that any growth shall take place before the piston goes into service; a final hardness of 80 to 90 Brinell is now considered all that is necessary or even advisable.

While an aluminium alloy piston only reaches about half the temperature of a cast iron one, power output has increased to a point where the centre of the crown may exceed 300° C. Further advances in the octane rating of fuels may soon bring us to the point where the strength of existing piston alloys is the limiting factor in design, there is therefore, an urgent necessity for the development of an improved type of alloy.

Aluminium Alloy Bearings

Another consequence of the increased power output of modern engines has been in many cases tin-base bearing metals are no longer able to stand up to the heavier duty. Lead-bronze bearings have been widely advocated but are expensive and not completely free from trouble. A number of aluminium alloys have been shown to give good results against hardened journals under light loading and with efficient lubrication, but they are generally oversensitive to edge pressures and variations in lubrication. A great deal of research has been carried out in this country and in Germany, where the shortage of tin is an added



Courtesy of Frys Diecasting Ltd.

Intricate Pressure Die-castings in Modified 10/13% Silicon Alloy.

incentive, in order to discover an aluminium base alloy that would give satisfaction under all working conditions. A hyper-eutectic type of alloy having a constituent of low solid solubility meets the generally accepted requirements of hard load carrying crystals embedded in a soft matrix, but experiments carried out on the continent with aluminium-copper and aluminium-silicon types have shown that it is also necessary to control the shape and size of the carrying constituents as well as their distribution in the matrix and the hardness of the matrix itself. Even so, these alloys seem to be prone to unexpected seizure if the bearing is not perfectly fitted or becomes distorted in service.

Research in this country seems to have been directed towards alloys having a eutectic of aluminium with a low melting point constituent such as tin or antimony, and load carrying constituents covering a range of widely different hardnesses so distributed as to prevent tearing-out during machining or breaking down of the oil film under conditions of poor lubrication. It is stated[2] that after exhaustive road tests these bearings have been adopted as standard on two types of engine manufactured by Rolls-Royce Ltd., which is without doubt the finest testimony to their quality.

Courtesy of British Aluminium Co. Ltd.

Aluminium Alloy Pistons ranging from those weighing a few ounces up to a 21½in. diameter Diesel piston weighing over 4 cwt.

Free-Cutting Alloys

The production of rods for machining in aluminium-zinc-copper mixtures was one of the earliest applications of extrusion to aluminium alloys, more recently considerable quantities of heat-treated alloys of Duralumin type have been used for the same purpose. Speed of machining and surface finish with these materials left little to be desired, but tool angles were rather critical and long, tough turnings were obtained that could not be continuously washed clear of the work. It is now generally recognised that these difficulties have been very successfully overcome as the result of extensive research work in America and later in this country and on the continent.[3] Free-cutting alloys are now available that are not over-sensitive to tool design and can show an actual saving in machining time as compared with leaded brass.

There are two schools of thought as to how free-cutting properties are best imparted : one advocating the addition of low melting point constituents of limited solubility such as lead, bismuth, tin, and antimony, to alloys of

Courtesy of British Aluminium Co., Ltd.

Parts machined in free-cutting Aluminium Alloy B.A.35.

Duralumin type, the other claiming that a brittle constituent is just as effective, avoids the difficulty of obtaining even distribution of such additions, and permits the use of alloys based on the aluminium-magnesium series having higher intrinsic resistance to corrosion. The majority of free-cutting alloys, among them the British and American versions, are of the first type, but in Germany, where perhaps political influences tend to encourage the use of magnesium, a considerable amount of attention is being devoted to the second.

Powder Metallurgy

Progress has not been entirely confined to the development of new alloy compositions, manufacturing methods have also received a great deal of attention. One of the most interesting innovations, which has virtually created a new branch of metallurgy, is the production of metallic articles from compressed and sintered powders, which had its beginning in the manufacture of tungsten and molybdenum bars and wire, but is now being extended to other metals and alloys, including aluminium. The production of an article in a pure metal is nearly always more easily accomplished by the normal casting and subsequent hot- or cold working, but for alloys that are difficult to cast homogeneously or to work after casting the method has great possibilities.

In view of the tenacious nature of the oxide film on aluminium particles, it is surprising that any intimate bond can be effected, but provided the right grade of atomised powder is employed the resulting mixture, after sintering, appears to develop the characteristics of an alloy made by normal methods and, in some cases, even to improve on them. So far, the only established use of sintered aluminium seems to be in connection with the nickel-cobalt-aluminium-iron alloys for permanent magnets, but the method might have advantages for the production

(*Continued on page* 150)

[2] W. C. Devereux, Inst. Auto. Eng. Coventry 9/11/37

[3] METALLURGIA May 1937

Manufacture of High-Strength Light Alloy Extrusions and their Use in Aircraft

By **R. WORSDALE**

The growth in the manufacture and use of extruded sections, particularly those which are generically referred to as "strong alloys of aluminium," has been phenomenal during the past three years. In this article, which is an abridgement of a lecture to the Gloucester and Manchester Branches of the Royal Aeronautical Society and the Medway Branch of the Association of Shipbuilding and Engineering Draughtsmen, the author discusses the mechanical aspects of their production and use.

IT is perhaps somewhat difficult to account for the rapid change—one might almost say an overnight change—in which steel, in the form of tubes and drawn-strip sections, has been superseded by light-alloy extrusions, but it is not proposed to discuss these reasons, it is sufficient to say that the change has been made, and made so rapidly that relatively few people are familiar with the method of manufacture of aluminium-alloy extrusions. Apart from the fact that aircraft designers have been very busy as a result of the expansion programme, the published data available regarding sections has been, until recently, very meagre, thus there has been little opportunity to study the subject. It is hoped, however, that this article, which will deal with the mechanical rather than the metallurgical, aspect of extrusion, will assist in the solution of design problems.

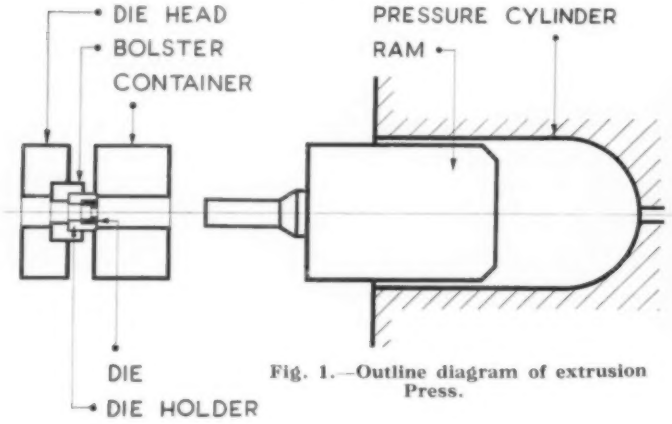
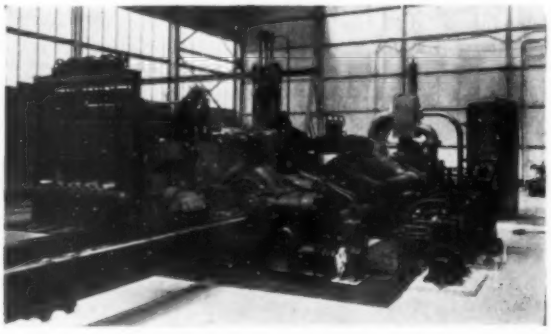


Fig. 1.—Outline diagram of extrusion Press.



Courtesy Reynolds Tube Co. Ltd.

Fig. 2.—950-ton extrusion press (control side) showing diehead withdrawn. Billet heating furnace in rear.

History of Non-Ferrous Extrusion

Before proceeding further, the history of the development of non-ferrous extrusion is interesting, and calls for some comment. Contrary to general belief, extrusion is not new: it has been practised in the lead industry for many years. It was not, however, brought into use with the general run of non-ferrous alloys until Mr. G. A. Dick, the founder of the Delta Metal Company, obtained his patents in 1894 for the extrusion of copper alloys. While the idea is extremely simple, its practical application presented many difficulties, and it was only by considerable ingenuity and patient work that Mr. Dick was able to make the process a commercial proposition. The monopoly of the process remained in his hands and that of the Delta Metal Company until the outbreak of the Great War in 1914, when, in order to assist in the more rapid production of munitions, the Delta Company agreed to forgo their patents in order to make the extrusion process available to all who required it.

From a practical point of view, the definition of extrusion is generally accepted as "the forcing of metal, heated to a plastic state, through dies, by pressure," and it is convenient to use the various operations indicated in that definition as headings for discussion.

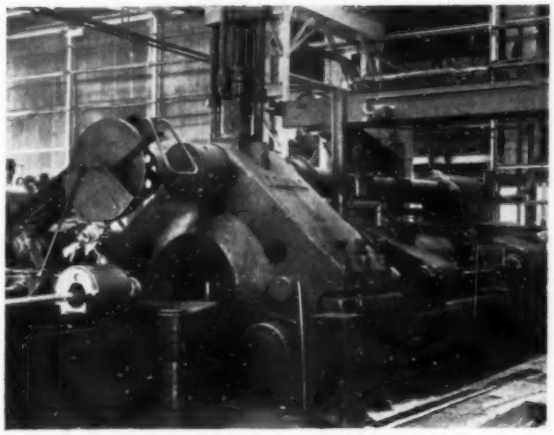
Forcing Metal by Pressure

The forcing of metal by pressure pre-supposes the use of some form of press. In some small presses used for brass the pressure is developed mechanically by a crank mechanism. For aluminium alloys hydraulic presses are preferred, since the pressure and speed can be more easily controlled. The hydraulic pressure necessary is usually supplied by the old type gravity or weight-loaded accumulator, or by one of the more modern air hydraulic accumulators.

Hydraulic extrusion presses, while they vary vastly in design and construction, are basicly identical. They consist of a container which receives the preheated ingot, or billet, to be extruded, the die, a pressure cylinder, and ram. The billet to be extruded is placed in the container, which is closed at one end by the die, and at the other by a pad, or pressure disc. Pressure is applied to this disc by the pressure cylinder, through the ram, the metal under this pressure being forced to flow through the die, and take the contour to which it is cut. (Fig. 1.)

There are two methods of extrusion—the direct and the indirect (or inverted). With the direct process, the container and the die are stationary, and the billet to be extruded is pushed by the ram through the container. In the inverted process the ram is stationary, and the container and die are pushed against this ram, which is hollow, so that the billet during extrusion does not move.

Presses can be vertical or horizontal. Vertical presses have the advantage, particularly where small power is concerned, of taking up less floor space than horizontal



Courtesy Reynolds Tube Co. Ltd.

Fig. 3.—2,000-ton extrusion press, showing diehead withdrawn after extrusion, preparatory to sawing off discard.

ones, but for practical reasons horizontal presses are generally used for the extrusion of solid sections. Vertical presses are frequently used for tubes, and are mounted above floor level, in order that the tubes can be removed easily after extrusion; sometimes a pit beneath is used.

The type with which the writer is most conversant is the horizontal direct-extrusion press, and it is the work of this type which it is proposed to describe in some detail.

Horizontal Direct-Extrusion Presses

These presses can vary in size from approximately 250 tons up to 6,000 tons. As far as the writer knows, no press larger than 6,000 tons has, as yet, been constructed *solely* for the extrusion of light alloys. These presses consist of the container, die, pressure cylinder and ram (Fig. 1). The container consists of a forged-steel circular body having an inserted liner made of nickel-chrome-tungsten heat-resisting steel, the latter being shrunk into position under pressure. This container, when mounted in the press, is surrounded by a chamber for heating purposes, the heating being supplied by gas or electricity. The ram, which is mounted in the pressure cylinder, is free to move horizontally backward or forward, actuated by the hydraulic valves which are controlled by the press operators (Figs. 2 and 3). By the use of hydraulic pressure an even flow can be maintained, and it can be regulated to very fine limits, which is especially necessary with aluminium alloys.

The die, which is mounted in a die-head attached to a slide, is located at the opposite end of the container to that at which the ram enters, and is held in position during extrusion by an hydraulically-operated wedge.

Preparation of Dies

In the die head there is fixed, in addition to the die plate, a die holder and a bolster. The die plate is the most intricate part of the preparation for extrusion, since on the successful cutting of the die depends almost entirely the successful extrusion of the particular section required. Before commencing to cut the die a templet is made by the die designer to the exact shape of the section, plus allowances for contraction, etc. From this templet the die is cut. The latter being a machined disc of nickel-chrome-tungsten steel $1\frac{1}{8}$ in. to $1\frac{3}{8}$ in. thick, varying in diameter according to the size of section and the press on which it is to be used. Some dies are partly machine cut, but all are finished by hand to extremely fine limits, and then highly polished (Figs. 4 and 5).

The die-maker's art, if one may call it such, is evidenced by the varying bearings which have to be allowed in order to ensure an even flow of metal through the die during extrusion. It is in making these allowances that the skill of the die designer is shown.

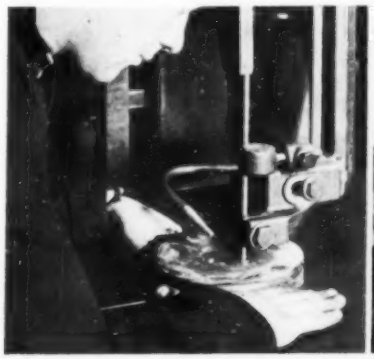


Fig. 4.—Die making—first stage. **Fig. 5.—Die making—completion.**

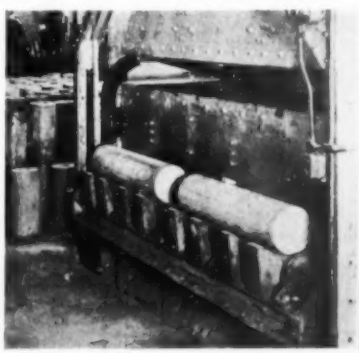
Fig. 6. Die, die holder and bolster before assembly.

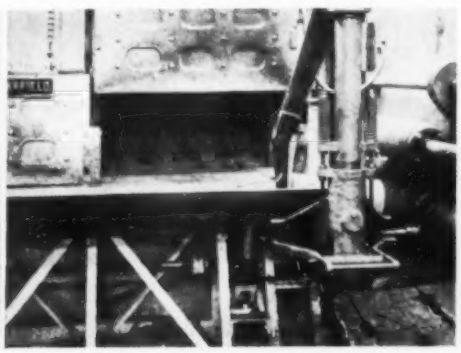
Fig. 7.—Die assembly.

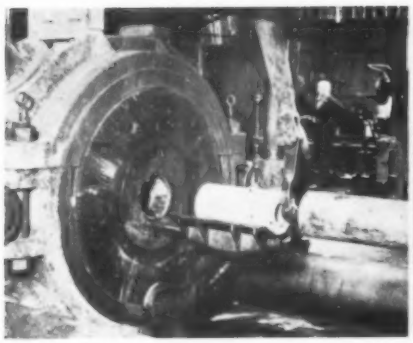
Courtesy Reynolds Tube Co. Ltd.

The die plate, against which the billet is forced, is cut square, no "radii" or "lead-in" being used for high-strength aluminium alloys. For magnesium alloys a slightly radiused die is necessary. Hence, it follows that dies cut for high-strength aluminium alloys can seldom be used for magnesium, and vice versa. The die plate itself, however, is not strong enough to withstand the very high pressure which is used. Special support is necessary, and a die-holder and frequently a special bolster are necessary. (Fig. 6). These two are of forged nickel-chrome-tungsten steel, cut to the same contour as the die plate, but larger, to

Fig. 8.—Loading billets mechanically. **Fig. 9.—Conveying billet to press.**







Courtesy Reynolds Tube Co. Ltd.

Fig. 10.—Inserting billet into container.

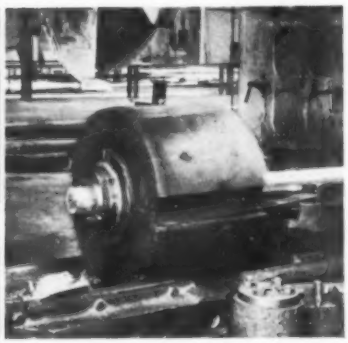


Fig. 11.—Diehead showing extrusion complete with discard cut off.

give free egress to the extrusion. These three tools, carefully hardened and tempered in automatically-controlled furnaces, when assembled fit accurately into the mouth of the container, so that no metal can escape during extrusion.

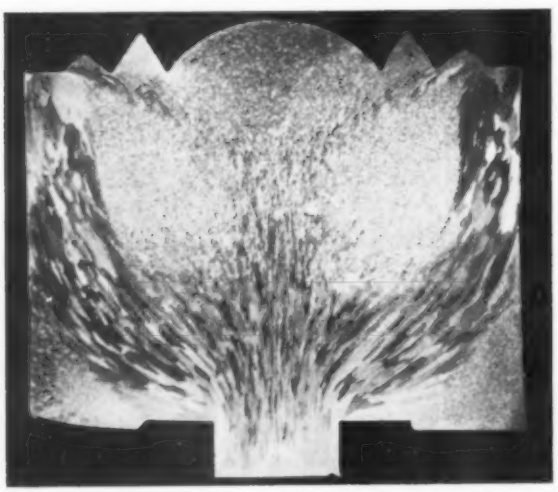
This die assembly (Fig. 7) fits into the die-head attached to the movable slide, and is pushed hydraulically into the mouth of the container, the hydraulic wedge lowered, and extrusion can commence. The dies are preheated to extrusion temperature before being placed in the die head to avoid chilling the billet.

Heating the Billets

The extrusion billets which are cast circular ingots varying in diameter and length according to the size of press and container being used, are heated in electric air-circulated furnaces to the particular temperature required, usually between 380° C. and 480° C. The furnaces have chain conveyer hearths electrically operated by push-button control. Some are manually fed when small billets are being used, others mechanically for large billets, the latter weighing up to ¾ ton for a 5,000-ton press (see Figs. 8, 9 and 10).

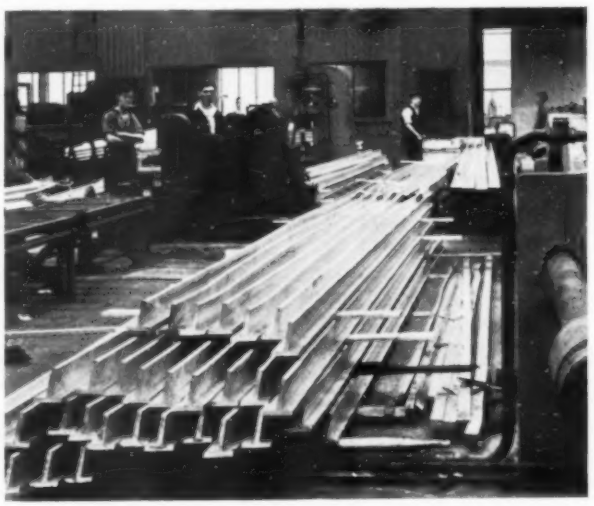
To prevent the metal flowing back over the stem of the ram during extrusion a presure disc is used. This disc, which fits the container with small clearance, is inserted after the billet, and against its rear face the stem of the ram operates. Were this disc not used, the stem of the ram, which has ample clearance to allow of its being withdrawn at the completion of an extrusion, would embed itself into the soft metal, and could not be withdrawn. A small portion of each billet, called the "discard," is left on each billet and is sawn off after the die-head is withdrawn (Fig. 11).

Fig. 12.—Discard showing flow of metal during extrusion.



The Flow of Metal

The flow of metal during extrusion is interesting, particularly when using the direct method of extrusion. All the metal adjacent to the die face is not forced through the die, only that directly opposite to the die aperture flows through As the metal is under pressure, and cannot expand outwards, being confined in the container, in order to move at all it must flow to the rear, and then down the centre (Fig. 12). If care is not taken during the operation, what is known as "coring" or "piping," will be present in the finished section. This phenomenon, which cannot be entirely eliminated, controls to some extent the length of discard allowed so that the extruded section is



Courtesy Reynolds Tube Co. Ltd.

Fig. 13.—Sections cut to length before heat-treatment.

Fig. 14.—Sections after heat-treatment, showing distortion.

perfectly sound throughout. All bars and sections of reasonable thickness are carefully examined for "coring" during finishing processes, and any defect found, eliminated.

It will readily be appreciated that during extrusion the metal is changed entirely from the cast to the wrought structure. The metal is, in fact, turned completely inside out, and, with the high pressure used during the process, extrusions have a dense uniform structure throughout. With the old method of producing rolled bars, the outside of the bar received plenty of cold work, while the centre of the bar was not always affected, retaining some of its cast structure, and therefore less reliable than the extruded bar of the same section and material.

(To be continued.)

The Use of Oxide Films on Aluminium and its Alloys

By Dr. E. G. West

Three electrolytic methods and a chemical process have become more general practice in the chief manufacturing countries for the formation of protective films. Each process is described and its limitations discussed.

IT has been said that the metal aluminium owes its existence to the natural film of oxide which covers its surface, and it is equally true that the continued expansion of the applications for which aluminium is particularly suitable depends on the increased use of artificially produced oxide films. Such coatings may be formed by purely chemical means or, more usually, electrolytically, and although originally employed to increase the corrosion resistance of aluminium, the unique properties of the film enable its use to be extended into many other fields. The actual composition of the film varies from one alloy to another, and depends also on the process used; but the order of thickness of films produced in different ways is as follows: Naturals, up to 10^{-5} in.; chemical films, up to 0·0002 in.; anodic films, up to 0·008 in.

The possibility of producing artificial oxide coatings was known for many years before commercial methods were developed, the first mention of electrolytic production being made by Buff[1] over 80 years ago. Little further was heard of this work until 1904, when Mott[2] published some interesting and prophetic observations; but although several patents were taken out between that time and 1923, it was not until Dr. Bengough and his collaborators published details of their process[3, 4] that industrial applications materialised.

During the past 10 years a considerable volume of research has been undertaken into the chemical and electrolytic processes, on the theoretical and practical aspects of the formation of films for a wide range of employment. This work has not been confined to any one country, the chief centres being Great Britain, U.S.A., Germany and Japan; but, until comparatively recently, each country favoured its own particular process. There has now been a certain consolidation of interests, and there are three main electrolytic methods and a chemical process in general use. Each process imposes certain limitations on the compositions of the alloys which may be successfully and economically treated, as noted in the descriptions given later.

Chemical Processes

All the chemical processes depend on the low solubility of aluminium in solutions, the *p*H values of which are between 4 and 8, and in practice alkaline solutions are employed. In such solutions uniform attack takes place until further action is inhibited by the insoluble compounds formed, often as a result of secondary reactions.

The method devised by Bauer and Vogel was described in 1915,[5] but there was little advancement until 1930, when the electrolytic processes were well to the fore. The M.B.V. (Modified Bauer-Vogel) process is typical of the simple immersion methods in use to-day, and consists of placing the articles into a solution of sodium-carbonate and sodium-chromate, maintained at, or near, the boiling point. The exact proportions are varied for different applications, the usual composition being 5% sodium-carbonate + 1·5% sodium-chromate (weighed anhydrous), and for certain purposes sodium-hydroxide may be added.

A later modification employs a 3 to 5% sodium-silicate dip (10 mins. at 90° C.) after the oxidation immersion, followed by a low-temperature heat-treatment, in order to increase the hardness and corrosion-resistance of the film. No preliminary cleaning is required, and 1 gal. of solution is stated to be sufficient for over 140 sq. ft. of surface. The normal immersion time is 10 mins., when a coating approximately 1μ thick is produced, films up to 7μ being obtained with immersion times of 2 hrs. The composition of a typical film formed on pure aluminium by this process has been given by W. Helling[6] as follows: Al_2O_3, 72·8%; Cr $(OH)_2$, 24·5%; NaO, 1·35%; Silicon (as SiO_2 and Si), 1·0%.

Chemical processes are suitable for a wide range of alloys, except those containing copper, the colour of the film varying from white and iridescent for aluminium to dark grey and black for alloys rich in other elements, particularly silicon. The films are too thin for the majority of applications, and it is usually necessary to employ one of the electrolytic processes.

Electrolytic Processes

Almost without exception the anodic oxidation processes in use to-day employ acids, with or without added salts or other compounds, the chief difference between the methods being in the electrolyte. The principal electrolytes are summarised with other information in the table.

Electrolyte.	Trade Names.	Normal Colour of Film on Aluminium.	Type of Current.	Average Power Used per Square Foot Surface.
				Kwh.
Chromic acid	Bengough-Stuart	Light grey Opaque	D.C.	0·15—0·2
Sulphuric acid	Alumilite Gower Sheppard Dialumin	Silver grey Translucent	D.C. or A.C. or both	0·05—0·2
Oxalic acid	Eloxal	Yellowish Opaque	D.C. or A.C. or both	0·4 min.

The solutions given in the table must be regarded only as the basic electrolytes, many additions—organic and inorganic—having been patented. Among the other proposed electrolytes are the following: Phosphoric acid and phosphates, using D.C. or A.C., and giving a grey translucent film; ammonia and ammonium compounds with D.C., to give a bluish-grey coating; boric acids and borates[7]; nitrates of the alkali metals[8]; pertungstic and permolybdic acids[9]; sodium hydroxide, with organic additions such as glycerine.[10]

Certain underlying principles common to each process may now be considered before discussing the three chief methods in detail. An essential preliminary treatment is the cleaning of the work by means of suitable solvents or alkaline cleaning solutions, otherwise contamination of the bath is unavoidable, the oxide layer will be non-uniform, and entrapped dirt would reduce the corrosion resistance of the film. When direct current is used the article is connected to the anode, and, in any process, the passage of the current subjects the work to intensive oxidation. The coating of oxide is built up progressively from the base metal; that is, the film may be considered to grow inwards, ions passing through the oxide layers already formed to attack the aluminium. The use of alternating

1 Buff. *Lieb. Ann.* 1857. 102. 269.
2 Mott. *Electrochemical Industry.* 1904. 2. 466.
3 Bengough and Sutton. *Engineering.* 1926. 122. 274.
4 Bengough. Dept. of Sci. and Indus. Res. Report. 1926.
5 Mitl. *Materialpfmt.* 1915. 33. 195.
6 Helling. *Aluminium.* 1937. 19 (6).
7 Van Geel and Emmens. *Physica.* 1934. 1. 415.
8 Masahiro Tazaki. *Tetsu to Hagane.* 1934. 20. 42.
9 Brit. Pat. No. 459263.
10 Brit. Pat. No. 429344.

current possesses certain advantages, and in some cases A.C. superimposed on D.C. is employed.

The properties of the anodic film, obtained by any of the processes, may be altered to a very considerable extent by variations in the operating conditions; these conditions including the type of current used, the applied voltage, the temperature of the bath, the time of immersion, pre-treatment of the articles, and the method of voltage regulation, when this is a feature of the process.

The oxide film, however produced, has a high electrical resistance, and relatively high voltages are therefore required—ranging from 10 to over 100, compared with the usual 2 to 6 volts for electroplating. As the resistance increases with the thickness of the coating, the current decreases during the operation if a constant voltage is applied. The rate of film formation being dependent on the current density, it is thus necessary to raise the voltage during the oxidation of a batch of work, or, alternatively, the time of immersion in the bath must be so regulated that no appreciable solution of the film by the electrolyte takes place. Obviously, if the rate of film formation drops below the rate of solution the net result will be extensive corrosion of the work.

The high resistivity of the film imparts to the process an exceedingly high throwing power, for all parts of an article must acquire a considerable oxide coating, otherwise severe local corrosion occurs. It is thus possible to anodise the insides of long tubes of small bore (for example, 10 ft. long × 1 in. bore), and also complex shapes, without the necessity of supplementary cathodes. The film thickness is not, however, uniform under such conditions.

The low conductivity also makes essential the provision of positive and reliable contact to the articles in the bath. A poor contact allows oxidation to take place between it and the work, thus preventing the formation of the requisite film. It must also be noted that only aluminium or suitable alloys can be used for contacts in the bath, as severe pitting and rapid solution of all other metals takes place at the anode.

The temperature of the solution is a very important factor in all anodising processes, due to the wide variation of the resistance of the electrolyte with small temperature changes, causing considerable alteration in the current density employed. The heavy currents employed generate sufficient heat in passing through the solution, and, to a greater extent, through the oxide layers, to increase the bath temperature very appreciably, and means of regulating the temperature are always required. For the same reason agitation of the solution, either mechanically or by aeration, is essential, this also ensuring uniformity of composition of the bath.

The composition gradually changes, due to reduction of some of the constituents at the cathode, and to the accumulation of impurities introduced from the work, or by solution of the film. The increase of resistance thus caused necessitates renewal of the bath at fairly frequent intervals, the appearance of the film being a very good indication of when this is required.

During treatment large volumes of oxygen are evolved at the anodes, and care must be taken in the handling and suspending of irregular shapes to avoid entrapping the gas, with resultant patches of poor film. The gases given off cause a spray which is harmful to the operators, and should be removed by suction. Care must also be observed in loading and unloading as the solutions are harmful on the skin, and adequate protection must be provided.

The Chromic-acid Process.—The original patent[11] specified a 3% solution of pure chromic oxide (CrO_3), free from sulphate and chlorides, and although modifications have been made, the usual solutions do not materially differ from this. The lowest limit for satisfactory anodising is 2½% CrO_3, and to avoid pitting of the film it is necessary to limit the chloride content to 0·20 grm. per litre (calculated as NaCl), and the sulphuric-acid content to below 0·50 grm. per litre. A.I.D. Instructions recommend the use of distilled water for the original solution, and for the additions made to replace evaporation loss, while it is allowable to add new chromic oxide, up to a total of 50% of the original weight, during the life of the solution.

The solution is usually contained in a welded tank of mild steel, but stainless steel is sometimes used. Although carbon plates were first used as cathodes, it is now the practice to use stainless steel, of the 14% chromium type, the chromic acid suffering less reduction with the latter. As the operating temperature is approximately 40° C. it is necessary to fit some means of heating to the vat, in addition to the cooling coils. Continuous filtration apparatus is sometimes fitted, but it is possible to remove only a proportion of the impurities by this means.

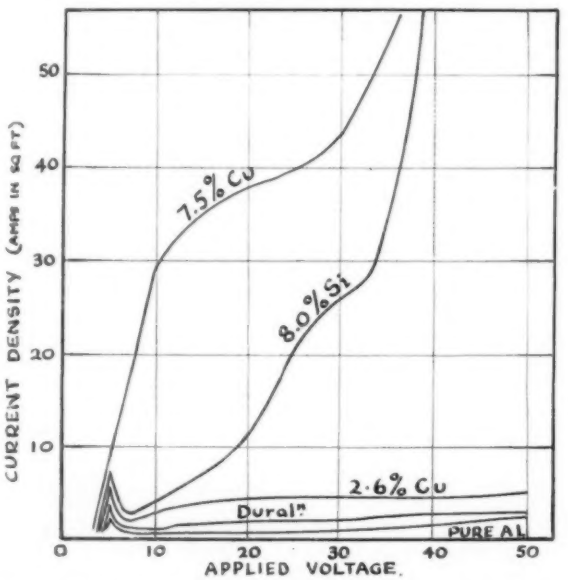


Fig. 1.—Voltage/current density curves for pure aluminium and typical alloys using the Benbough process at 40° C.

Direct current is supplied by a motor-generator, with means of controlling the output voltage, the various instruments, switches, resistances, etc., being most conveniently placed on a panel near the vat. It is important that the lowest voltage obtainable should be not more than 4 volts, otherwise a considerable surge of current is obtained when the switch is first closed, due to the low resistance of the circuit.

The voltage is gradually increased in the first 15 mins. up to 40 volts, which is then maintained for 35 mins., when it is taken to 50 volts in the next 5 mins. This is held for a further 5 mins. and the current switched off, making a total time of 1 hour per load. The anodised articles must now be swilled well in hot water, followed by cold water, to remove all traces of electrolyte, which is retained in the pores of the film, and in any cracks, joints or holes in the base metal.

The current density varies according to the alloy, and is dependent on the temperature. Normally, 3 to 6 amps. per sq. ft. are required, but an increase of even 5° or 6° C. is sufficient to double these figures. Increasing quantities of alloying elements cause large increases in the current density obtained at given voltages and temperaturess examples being shown in Figs. 1 and 2. Normally, alloy, containing less than 95% aluminium are not treated by this process, but it is still the best method for the duralumin type.

Two methods of modifying the original process have been used—additions to the solution, such as alkali chromates and dichromates, and variations in the operating conditions. The latter is the more usual way, voltage, temperature and immersion time being altered to suit a

11 Brit. Pat. No. 223991.

APPLIED VOLTAGE

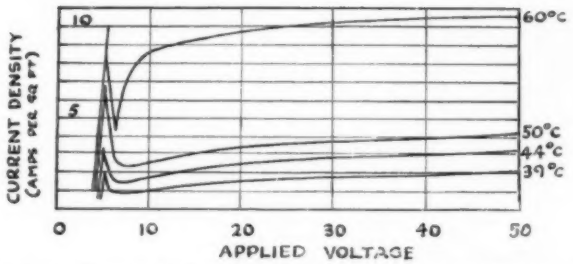


Fig. 2.—Voltage/current density curves for duralumin at varying temperatures.

particular alloy or application. The formation of softer, more-porous films is favoured by increase in temperature, while increase in the applied voltage acts in the reverse direction, but the composition of the alloy limits the maximum e.m.f. that can be employed. Many of the proposed modifications aim at reducing the attention required by the operators, and a suggested method of continuous working has been published in America.

The Bengough-Stuart process was the only method approved by the Air Ministry until recently, and is still the most widely used process in the world; but a comparative decline in its employment is to be expected, due partly to the disadvantages of the batch loading.

The Sulphuric-acid Process.—Since 1927 a large number of solutions having sulphuric acid as their principal electrolyte have been proposed, as reference to the patent literature shows,[12] and a number of descriptions of specific processes have appeared, particularly the Alumilite process.[13] All compositions from less than 7% to over 70% by weight have been suggested, but the best concentration coincides with that of maximum conductivity (19·5%), the usual commercial range being from 9 to 20%. Industrial baths usually contain sulphuric acid of a definitely maintained concentration, without addition agents, many of which have been tried, with only slight success. Among these added substances are sulphates of the alkali and heavy metals; organic acids, such as acetic, oxalic and citric, with or without their salts; other organic compounds—alcohols, aldehydes, sugars, sulphonated products, etc.; oxidising agents, such as dichromates; tungstic and molybdic acids. The difficulty of ascertaining the composition of the solution with many of these additions is apparent, and they have little commercial importance.

The sulphuric-acid electrolytes require tanks lined with lead or glass, and when cathodes are used they are also of lead, the vat sometimes serving this purpose. Equipment for heating, cooling and agitation is usually incorporated in the design of plants, and fume extraction apparatus should be provided, although not yet essential.

As might be expected, wide variation is shown in operating conditions—temperatures from 15° to 90° C., and applied voltage from 10 to over 30, the higher figures being required with lower concentrations of acid. Either direct or alternating current, or both, may be used, and current densities, again depending on the temperature and the alloy, range from 1 to over 40 amps. per sq. ft. The time of immersion is usually just over 30 mins., with limits of about 10 to 50 mins., while the applied voltage is not normally varied, although an interesting patent[14] details a method, employing A.C., with the voltage increased from 9 to 24 volts during the first few minutes of the process. Compared with the Bengough process, the lower non-varying voltage usually employed reduces the cost of the electrical equipment and enables continuous operation to be practised instead of batch loading, but handling difficulties are thereby introduced. Fig. 3 illustrates graphically the differences in operating conditions for typical chromic and sulphuric-acid processes.

The electrolyte gradually deteriorates, due chiefly to solution of the film, which is more rapid than in the previous process, and a new solution is required when the aluminium-sulphate content reaches approximately 20%. This figure is influenced by the presence of other metals, dissolved from the alloys treated, the difference being very great when highly alloyed material is concerned with aluminium contents sometimes as low as 80%.

The films produced are always more transparent than those given by the chromic-acid process, and the maximum hardness obtainable is slightly greater. The hardness is influenced by the bath temperature—up to 90° C. being employed in the production of soft, flexible coatings.

The Oxalic-acid Process.—Oxalic acids was first used as an electrolyte in 1928, and although many modifications have been described[15, 16] the process is not as extensively used as the other two. The usual bath compositions range from 3 to 7% by weight, but lower and higher percentages are also used. Compositions approximating to a normal solution are often favoured, and additions are recommended—either of a colloidal nature or oxidising agents, the latter being usually employed in the form of chromates, dichromates and permanganates. Sodium silicate has been used, and also recommended are oxalates and other organic salts, caustic soda and strong inorganic acids, except those of the halogens.

The anodising conditions vary over wide ranges—the voltage from 30 to over 100, and temperatures from 15° to 40° C. Direct and alternating current are used—often both,—and the current densities are high, approximately 40 amps. per sq. ft. being common, while the time of immersion runs from 10 to 50 mins. The best films for corrosion resistance are formed at the higher temperatures, with low-current densities and high-acid concentration. Freedom from pitting and greater hardness are obtained by the use of A.C. alone, or superimposed on D.C.

Oxide coatings produced in this electrolyte are opaque and yellowish in colour, and are harder than those obtained in either of the other solutions, but the process is considerably more expensive to operate.

Other Processes.—There has been little published on the other methods mentioned, and they are employed industrially in isolated special cases only. An interesting process was described in 1934,[17] whereby a film was produced by the use of an electrified spray of solution, thus enabling large articles to be anodised in situ. Extensions of this idea should certainly be seen in the future.

It must be stressed that experiment is still required to determine the optimum conditions of treatment for any particular alloy or purpose, and having ascertained these, success on a commercial scale can be achieved only by strict adherence to all the details of the operation, combined with close control of the analysis and physical condition of the alloy.

[Properties of anodic films, finishing, testing, influence of the base metal, and general applications of anodic films will be discussed by the author in the March issue.]

12 Typical Patents—British, 280901, 401579, 436154, 474608. U.S.A., 1900472.

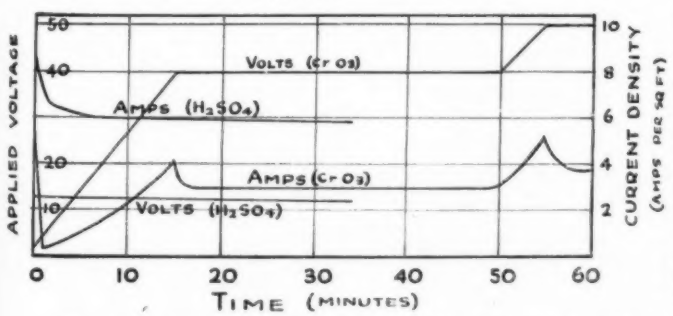


Fig. 3.—Comparison of operating conditions for 3% chromic-acid bath at 40° C., and 12% sulphuric-acid solution at 20° C., using commercial aluminium.

13 For example—Bengston and Pettit. *Machinist* (cur Edn.). 1933. 77. 76. Herrmann. *Chimeiz. Tech. Zeitsch.* 1933. 8. 285.
14 Brit. Pat. No. 474704.
15 Sternberg. *Werksleiter.* 1931. 5. 336.
16 Setoh and Miyata. Sci. Papers. Inst. Phys. Chem. Res. Tokyo. No. 396. 1932. 189.
17 Lowenthal. *C. Abs.* 1934. 28. 2275.

Aluminium Die Casting

By

Dr. ARTHUR STREET

Aluminium plays an essential part in the constitution of practically every alloy that is die cast, but in this article attention is directed more particularly to the aluminium-base alloys which represent a considerable proportion of the bulk of die-casting output. Reference is also made to the progress in die casting pure metal.

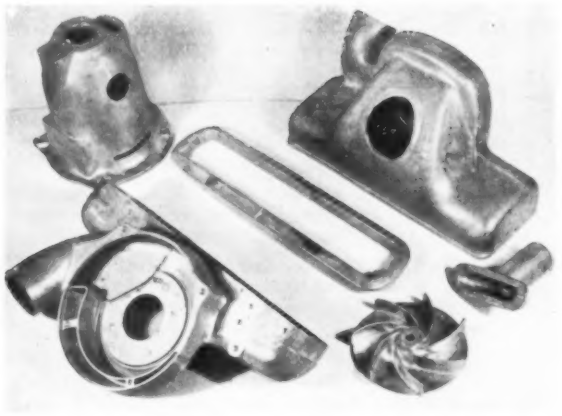


Fig. 1.—Group of pressure die-cast vacuum cleaner components.

THERE is hardly an industry which does not in some way utilise die-cast products and certainly, in our ordinary life it is difficult to pass a day without using die cast articles in home, automobile and factory. Perhaps it is out of place to introduce a domestic note into a technical paper, but most readers will appreciate the saving of trouble which vacuum cleaners, washing machines, cream mixers and compact wringers have brought to their households, and they will certainly realise that the bulk production of these amenities at low cost has been rendered possible largely by the adoption of die castings in their manufacture. As Fig. 1 will suggest, the vacuum-cleaner industry is one of the major consumers of aluminium-alloy pressure die castings, and several of the well-known models employ as many as a dozen such castings in their construction.

The general principles of the process are so well known that it would be redundant to elaborate them here, but it is worthwhile reminding ourselves that the industry is divided into two groups, making "gravity" and "pressure" die castings—the former being produced by pouring the metal into permanent moulds, and the latter method being essentially a quantity production process, involving the pressure injection of the alloy in a liquid or plastic condition into a water-cooled alloy-steel mould, mounted on what is usually an elaborate and expensive pressure die-casting machine. Gravity die casting usually becomes an economical proposition where amounts of 500 and upwards are required; Fig. 2 will indicate that aluminium-alloy gravity castings may attain a considerable complexity and good surface appearance.

Although the pressure die casting yields a more accurate, and, if necessary, complex job, the cost of tool-making and setting-up are so considerable that this process rarely shows its real economy until numbers greater than 5,000 per annum are required. For large-number production of the order of 50,000 and upwards, the pressure die-casting process becomes one of the most valuable methods of fabrication by reason of its cheapness, high production speed, and because the pressure die-cast article maintains dimensional accuracy, strength and surface appearance: Fig. 3 shows a pair of binocular bodies, pressure cast in 12% silicon-aluminium alloy; the prevailing section is about $\frac{1}{16}$ in., so that, although the binoculars are $4\frac{3}{4}$ in. long, the pair only weigh $4\frac{1}{2}$ oz.

It seems likely that the use of both pressure and gravity methods will continue to increase, for almost every day finds new applications for die casting. At the present time, chiefly because the motor trade still buys its aluminium die castings in the gravity form, the output by this process exceeds that of the pressure die casting, but with the developments and improvements in aluminium-alloy pressure casting, it is possible that the modern process will in due course outstrip the simpler gravity method. This article will chiefly discuss pressure die casting.

It is interesting that aluminium plays an essential part in the constitution of practically every alloy which is die cast. The zinc-base group—so widely used for automobile fittings, embody about 4% aluminium; the high-tensile metal, aluminium bronze, contains aluminium 10%, and the balance copper. The aluminium-base alloys which to-day represent a considerable proportion of the bulk of die-casting output may be divided into seven groups: (1) Commercially-pure aluminium, (2) aluminium-copper alloy, usually of "L. 8" composition, (3) aluminium alloy usually with 11—13% silicon, (4) aluminium-copper-silicon alloy, (5) "commercial" alloys containing copper, iron, silicon, zinc, etc., (6) heat-treated alloys—e.g., "Y" alloy, (7) alloys containing low percentages of certain added elements making anodising practicable.

Fig. 2.—Gravity die-cast electric drill body.

Courtesy of Messrs. Desoutter Bros. Ltd.

Fig. 3.—Pressure-cast binocular bodies.

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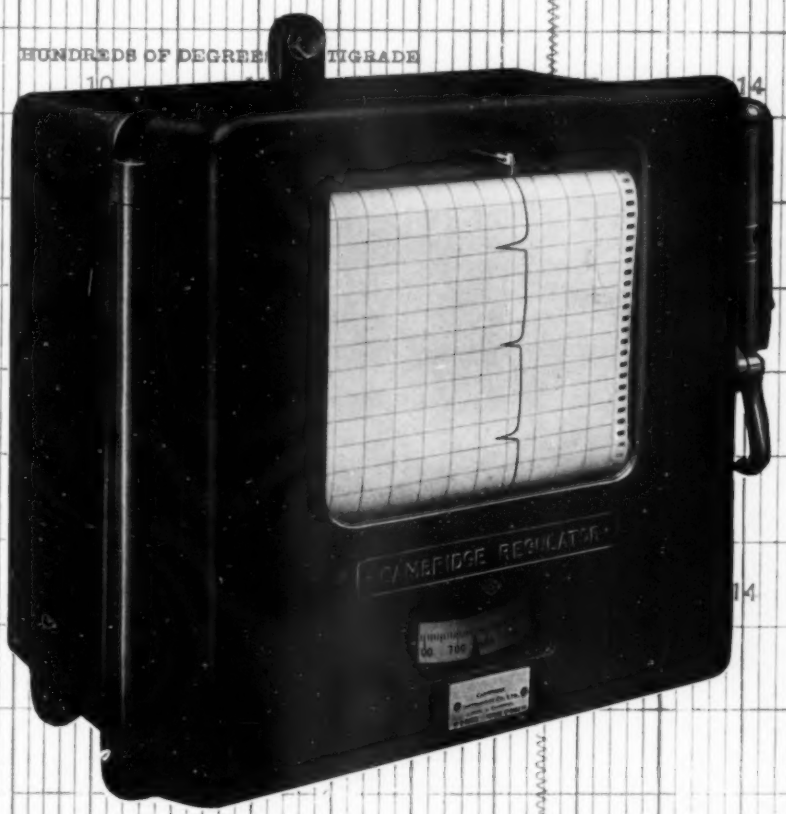

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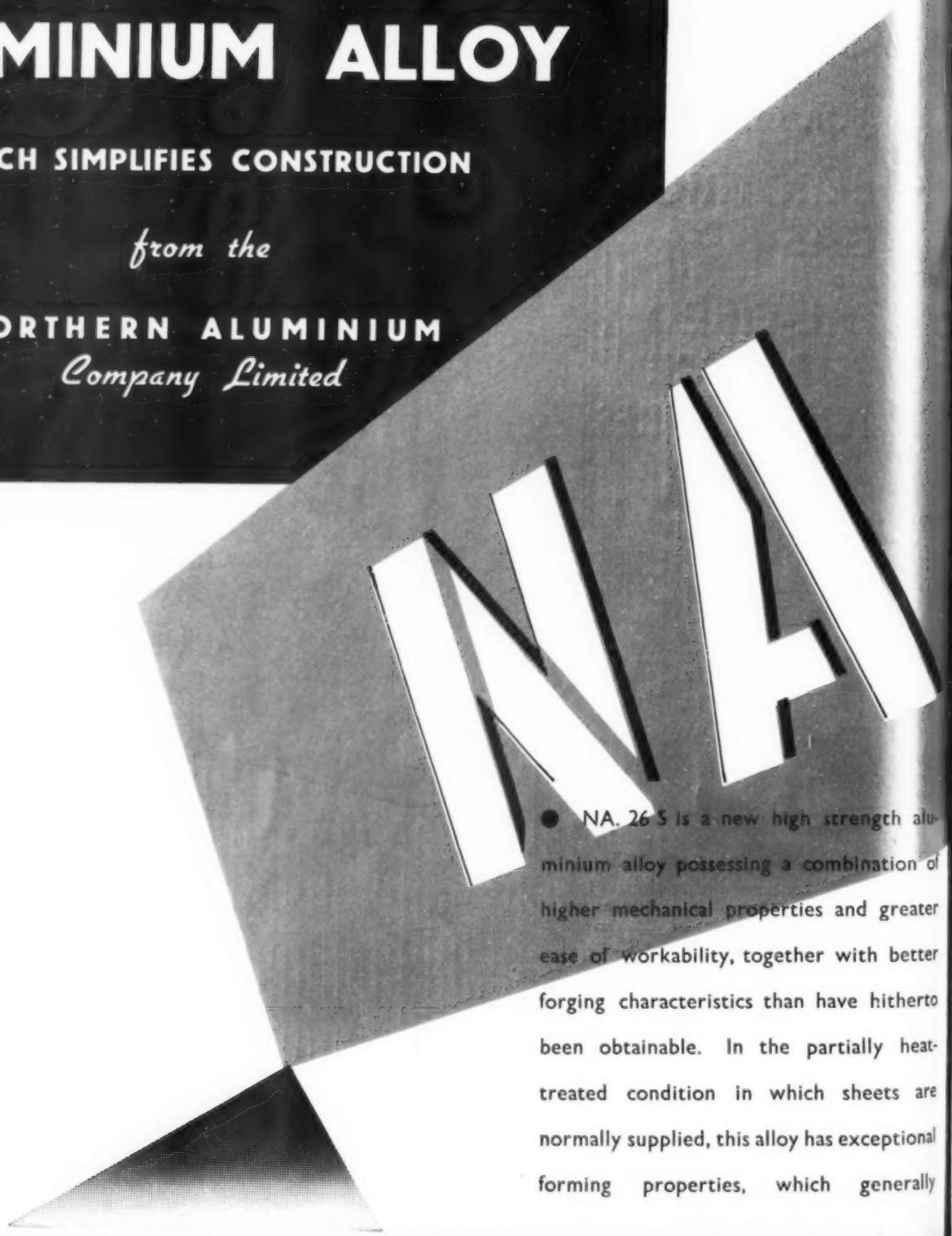

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Ultimate Tensile Strength tons/sq. ins.	25.0	27.0	30
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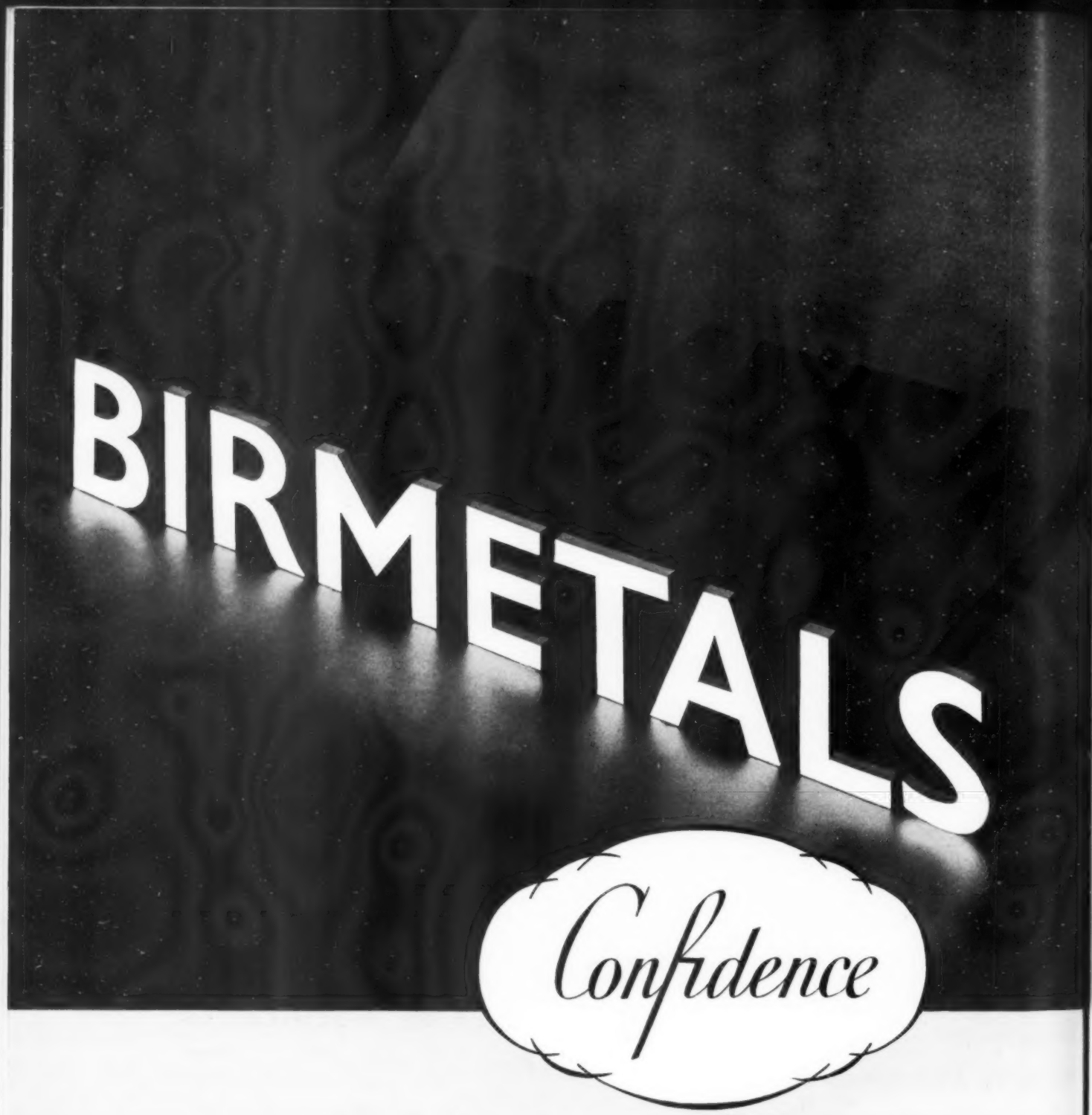

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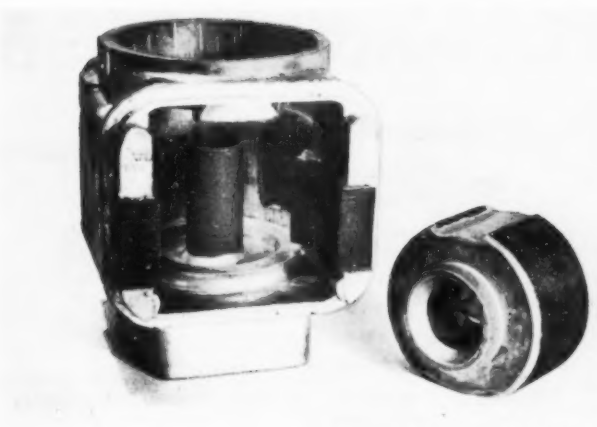


Courtesy of Messrs. Wico Electric Company.

Fig. 4.—Magneto housing and armature.

Courtesy of Messrs. Fax, Limited.

Fig. 5.—Pressure-cast juice extractor body and cream mixer stand.

Die-Casting Pure Aluminium

Although die-casting output is principally devoted to the fabrication of alloys, yet a consideration of the possibilities of die casting pure metals might be interesting. From a user's point of view aluminium has several advantages. It has high thermal and electrical conductivity —e.g., the pure metal has a conductivity 64% that of copper, while with a 12% silicon alloy the figure is only 40%. The corrosion resistance of aluminium and the non-toxicity of its compounds render it specially suitable for the making of articles which must be in contact with foodstuffs. However, from the die caster's point of view, the pure metal has two disadvantages. It is weak at temperatures directly below the freezing point; the stresses in rapidly-chilled die castings are such that a metal which is hot-short will contract in the mould, due to the constraint of the features of the die as the casting contracts. No matter how quickly the operator opens his mould and withdraws the cores, a hot-short metal, die cast in a complex tool, will develop cooling cracks. Recent improvements in commercially-pure aluminium have rendered it more amenable to die casting, but it is still necessary that the shapes which are attempted shall not be too elaborate.

The other feature which renders pure-metal pressure casting difficult is that the metal solidifies rapidly and without an intermediate plastic condition; in the pressure process such a type of freezing makes it difficult to remove entrapped air before the die casting becomes solid. In the gravity process where the metal is in a more tranquil condition this difficulty does not arise, and there is one type of die casting, called "slush" die casting, where the instantaneous freezing of a pure metal or eutectic becomes of value. In the making of, for instance, teapot spouts, the external shape of the job is cut as usual in the two halves of the die, but no core is provided for the central hole. Pure aluminium is poured into the die, and almost immediately this mould is reversed, so that the portion of the metal which is still liquid is tipped out. The chilled metal in direct contact with the die solidifies first, so that the finished product with the correct-shaped central hole is left remaining in the mould. If an alloy with an appreciable freezing range were "slush" cast, the reversal of the die would cause the still molten interior metal to be accompanied by portions of the semi-solidified outside layer.

With the better understanding of pure-metal die casting it is likely that this phase of the industry may become more prominent for applications where the special properties of pure metal are more important than, say, tensile strength. At the present time an interesting development of this branch of the process is being applied to rotor construction. The steel laminations are clamped together, and the assembly is held in the die as an insert. Pure aluminium is pressure-cast around these laminations, and during cooling the effect of the insert is to give rigidity and support to the contracting metal. Fig. 4 shows an illustration of a magneto main housing and its armature, the latter being pressure cast in aluminium. The laminations and rotor-bearing stud are cast in place as inserts in the aluminium-silicon housing and the magnets and laminations are included in the pure-aluminium rotor.

Aluminium-Silicon Alloys

The aluminium-silicon alloys are a particularly interesting group as regards the pressure industry. The alloys are sufficiently fluid at temperatures little above their melting point to enable them to be pressure cast at a lower temperature than those of the other alloys. This means that die life will be longer and unsoundness will be easier to eliminate; a pressure die-cast 12% silicon-aluminium alloy can be produced with pratically complete freedom from porosity. For reasons mentioned above, the main cause of the wide use of aluminium-silicon alloys is that die casters like them, but they are valuable, also, in that they offer a combination of good resistance to corrosion with a reasonably high tensile strength in the die-cast condition—between 12 and 14 tons per sq. in. Fig. 5 illustrates two articles where the die casting is in contact with food products and the corrosion resistance of the silicon alloy is of definite value.

In passing, the writer would like to draw attention to an interesting phenomenon met with in the pressure casting of these aluminium-silicon alloys. The structure of the metal closely resembles that attained by the modification process; for instance, a 12% alloy which normally is of about eutectic composition, will in its pressure die cast condition have an outer skin about $\frac{1}{8}$ in. thick of modified eutectic plus an appreciable amount of primary aluminium. The lack of equilibrium brought about under the rapid chilling causes a shifting of composition first to the left and then to the right of the eutectic point, and thus towards the interior of a pressure die casting we may have modified or semi-modified eutectic plus both primary aluminium and fine needles of primary silicon. One wonders whether this effect may throw some light on the phenomena of modification; certainly, from the point of view of the user of aluminium die-castings the "modification" is of considerable value, for it means that a pressure casting will be appreciably stronger than a similar alloy in the sand-cast condition.

There are some disadvantages which make it necessary to consider the use of other aluminium alloys such as those previously referred to. The aluminium-silicon alloy is much more expensive in raw material cost than the "commercial" alloys. It is significant, however, that

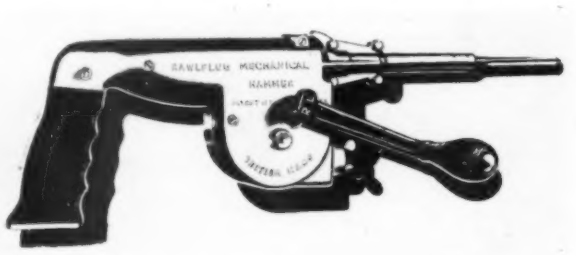
accuracy, die life, strength and corrosion-resistance offered by the aluminium-silicon alloy pressure die-castings do bring about a wide and ever-increasing use of this material; but several of the other compositions specified above are quite widely used in the gravity industry. The aluminium-silicon alloy when polished has a bluish colour which is not so attractive as the whiter appearance of, say, the alloys containing small amounts of copper and magnesium only.

There is a third point which may sometimes prevent the use of the silicon-aluminium alloy; the composition will not anodise into a condition that will take a tinted finish, although if a non-coloured coating, for protection only, is required, an anodic film can be applied and, incidentally, there are chemical finishes on the market which give a similar protective coating. It seems that if an alloy is in a duplex condition, although it will anodise, the coating thus applied is non-homogeneous, so that a light-coloured tint gives a patchy appearance. If an alloy is employed containing small amounts only of certain added elements, the metal will be in a single solid solution condition, and will take a tinted anodised finish. Unfortunately, such compositions are difficult to pressure die cast, although at the present time alloys containing low percentages of magnesium and copper can be pressure cast for not too elaborate articles.

The aluminium alloys are by no means easy to die cast, particularly when the pressure process is applied. They have high contraction, and also they cling to the steel of the die, so that cores must be tapered in order to allow their easy withdrawal. To give an illustration, if a die casting were produced in zinc alloy, a hole 2 in. long and ½ in. diameter would have to be tapered about 0·004 in. on its diameter, while, if the same job were produced in aluminium alloy, the necessary taper would be five or more times this figure. The surface tension effects coupled with the comparatively high melting point of the alloys mean that die construction must be carefully considered. It is wisest to use an alloy steel mould; usually the main die-blocks will be in chrome-vanadium steel, while slender cores may be cobalt chrome or tungsten steel; the die is cut in the soft condition, and the first few samples will be die cast in the unhardened mould. Before bulk production, the die is carefully heat-treated, and if well made, will last probably 50,000 shots or more. A badly-made or incorrectly heat-treated mould will give trouble before it has produced 500 castings.

Factors which Determine Choice of Process

Usually, it is easy to judge whether a proposition will be more suitably dealt with by the pressure or by the gravity process. There are several questions which are generally asked in deciding. What quantities will be required per annum? If less than 5,000 are involved, it is likely that the low die cost and setting-up charges of the gravity method will make it more attractive from an economic point of view. What speed of production is needed? A gravity tool will work at between 100 and 250 castings per day, while a pressure die will produce anything between 250 and 1,300 per day, depending on the size and complexity of the job. What degree of accuracy is required? A gravity casting will maintain an accuracy of about plus or minus 0·005 in. per inch, while in a pressure die casting the tolerance will be plus or minus 0·002 in. per inch. What are the design features of the part? There are certain jobs which can really only be satisfactorily produced on a manually-operated gravity die, because their designs include undercuts which involve the hand manipulation of collapsible cores. Other types of undercuts involving "knock-out" cores can, however, easily be achieved by the pressure process. Thus, the usual design of automobile piston involves undercuts which render the part more suitable to gravity die casting, while the vacuum-cleaner body included in Fig. 1 contains an undercut which may without difficulty, be achieved in a pressure die casting. There is little difference in the cost of a suitable gravity die casting, and a suitable pressure die casting so that the choice of which method is to be used generally depends on considerations such as those listed above.



By Courtesy of Messrs. Rawlplug, Limited.

Fig. 6.—The major part of this mechanical hammer comprises aluminium die castings.

Uniform Sections Desirable

A few other essential principles are equally simple to grasp. The section should be kept as uniform as possible to ensure regular chilling of the product. Sharp corners should if possible be avoided; lettering should be raised. Small holes should be avoided because they involve the presence of slender cores which suffer deterioration under the repeated impact of the liquid metal. Particularly does this apply to holes near the runner position, for here the metal will be at its maximum velocity and temperature.

One of the most interesting features of the application of die casting is the way in which design can be planned so as to reduce the cost of the article and at the same time improve its appearance and saleability by the use of die-casting methods. Fig. 6 illustrates a well-known mechanical hammer after it had been improved by the use of an aluminium-alloy pressure die casting.

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T.G.S.

American Progress in the Utilisation of Aluminium and its Alloys

By

ROBERT J. ANDERSON, D.Sc.

As a result of important advances in the development of new alloys, the use of aluminium has extended to purposes for which it was previously uneconomic in competition with other metals and materials. Some fields in which conspicuous progress has been made in the United States of America are described, together with the trend in market expansion.

THE number of individual uses for aluminium and its alloys has increased remarkably in the United States during the last decade. Formerly, the bulk of metal was consumed here by automobile manufacturers, public utilities, and utensil makers, but the development of many new applications in recent years has greatly enlarged the market. Numerous industrial consumers in this country have lately applied aluminium in place of other metals for the manufacture of various products. This trend is quite conspicuous. It has been due for the most part to aggressive sales promotion by the Aluminium Company of America. Moreover, scientific research and development work by this company have resulted in many new uses and increased the demand for well-established applications. It is worth noting that the market for aluminium expanded in the United States during the years of the recent industrial depression when prices of copper and other competitive metals were very low. Concurrently, the relatively high price of aluminium was maintained.

Technological progress in a number of directions has broadened the market for aluminium products. The most important advances have been made in connection with the development of new alloys, methods of fabricating, new equipment for processing, heat-treatment, welding, structural design, and surface finishes. As a result, the use of aluminium and its alloys has been extended to purposes for which they were previously uneconomic in competition with other metals and materials. The various new aluminium products which have recently been offered reflect these advances.

Special or improved equipment has made practicable the production of structural shapes, heavy plates, forgings, tubing, and sections in a wide range of sizes. Some of these manufactures are employed instead of the corresponding steel products for the assembly of structures, notably, railroad cars and bodies of motor-trucks and buses. Structural shapes up to 85 ft. long and up to 12 in. channels are now rolled. Plates are produced up to 3 in. thick, about 10 ft. wide, and 35 ft. long, but weighing not more than about 1 ton. Round, square, oval, and streamlined tubing is currently made in sizes up to about 11 in. as measured on the largest cross-section. Thousands of complicated forms are now produced by the extrusion process, especially for architectural and structural purposes.

The use of Alclad products in aircraft construction has increased substantially. A development of particular interest is the coating of aluminium manufactures by anodic oxidation. The process has been markedly improved so that the properties of the coating can now be controlled. Methods for the production of hard coatings which are exceptionally resistant to abrasion have been worked out. Such hard coatings are applied to pistons and other wares. Also, an electrolytic treatment for aluminium has been devised. It is known as the Alzak process. By this treatment the reflectivity for light of a polished aluminium surface is increased more than 20% and the metal is rendered proof against tarnishing. Fig. 1 shows the Novalux sodium lamp with Alzak-treated aluminium reflector as supplied by the General Electric Co. for lighting highways.

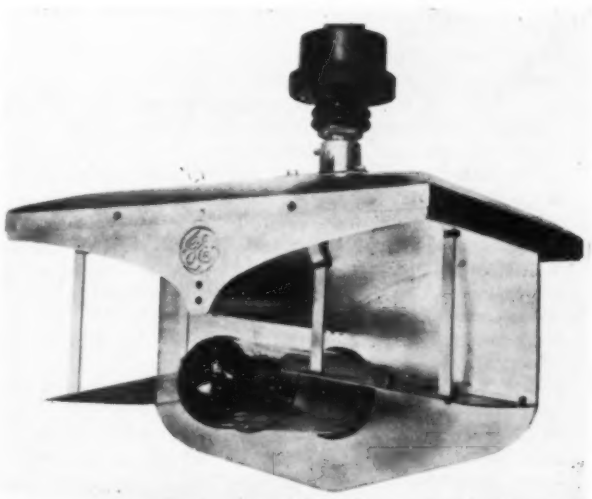


Fig. 1.—Novalux sodium luminaire with aluminium reflector (General Electric Co.).

As is known, recent progress in the United States with regard to the utilisation of aluminium and its alloys has been generally similar to that in other industrial countries. At the same time, some American applications have been outstanding. The more notable achievements in this country of late years are reviewed briefly here, and the probable trend of development over the near term are indicated.

Aluminium Alloys

In respect of aluminium alloys there has been a marked tendency in the United States towards the use of special compositions for particular purposes. A number of new alloys have been introduced since 1930 by the Aluminum Company of America. These include compositions for the production of castings and of wrought manufactures.

Heat-treated castings are employed extensively in this country and have been made mostly of aluminium-copper base compositions. The newer aluminium-silicon base alloys containing a small amount of copper and/or magnesium (Alcoa Nos. 355 and 356) are, however, now being used considerably. These compositions are well suited for heat-treated parts which are difficult to cast. Furthermore, the heat-treatable composition containing 10% magnesium (Alcoa No. 220) is being employed in place of other alloys where high strength and resistance to shock are required. Other binary aluminium-magnesium

Fig. 2.—Sikorsky flying boat (Sikorsky Aircraft Division of United Aircraft Corp.).

alloys have found application recently in the United States. One composition contains about 4% magnesium (Alcoa No. 214). This is used in the as-cast condition, particularly for parts to be exposed to sea water and other corrosive agents.

The standard 5% silicon alloy (Alcoa No. 43) is still used widely for sand castings and is favoured for architectural parts. Several aluminium-copper-silicon and aluminium copper-nickel-silicon alloys are employed for pressure die casting. Aluminium-copper base compositions for cast pistons have been supplanted considerably by the high silicon, complex alloy known as Lo-Ex (Alcoa No. 132). The thermal expansion coefficient of this alloy is only about two-thirds that of the older piston alloys.

The practice evolved in the United States during late years in connection with the utilisation of secondary metal is worth noting. Alloys of rather indefinite composition are made by melting miscellaneous cast scrap which has been properly sorted and blended, if necessary. Such scrap may yield pig metal having the following approximate range of composition: aluminium, 84 to 90%; copper, 4 to 7%; silicon, 2 to 5%; zinc, up to 3%; and iron, up to 1·5%. Up to about 0·5% each of manganese and nickel may be present. There may also be contained a few tenths per cent. each of magnesium and tin, and a few hundredths or thousandths per cent. each of antimony, calcium, lead, silver, sodium, titanium, vanadium, and other elements. Complex alloys within these limits meet all requirements for various casting purposes. Large quantities of such alloys are used by independent founders for the production of automotive and other castings under specifications which emphasise performance rather than composition.

Several new alloys have been developed for the production of wrought manufactures and have considerably superseded the older compositions. Thus, while ordinary duralumin is still used extensively, a modified composition containing about 1·5% magnesium (Alcoa No. 24S) is now preferred for aircraft construction and other applications where maximum strength is required. Fig. 2 shows the famous Sikorsky S–42 Clipper ship which is constructed mostly of 17S and 24S products. A duralumin type alloy which contains no magnesium (Alcoa No. 27S) is now employed for rolling structural shapes and for forgings. Also, forged pistons for aircraft engines are being made of a high silicon, complex alloy (Alcoa No. 32S) of the Lo-Ex type.

Among other wrought heat-treatable alloys which have been developed recently is a composition of the aluminium-magnesium silicide type containing about 0·25% chromium. This has high resistance to corrosion irrespective of the heat-treatment. Another new class of alloys for wrought products is represented by aluminium-magnesium compositions. These contain small percentages of magnesium alone or with other elements. Such alloys are not heat-treated but may be work hardened. They possess excellent resistance to corrosion by sea water and atmospheres together with high endurance limit. The above groups of alloys are being employed in the construction of buses and

Fig. 3.—Streamlined, high-speed train of aluminium construction (New York, New Haven and Hartford Railroad Co.).

Fig. 4.—Electric shovel with aluminium-alloy dipper (The Marion Steam Shovel Co.).

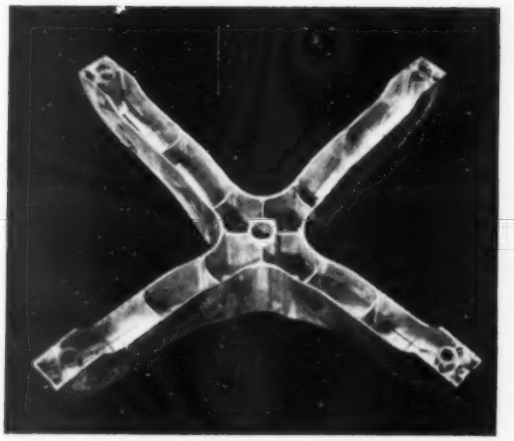


Fig. 5.—Base for swivel chair; die cast in an aluminium alloy (Doehler Die Casting Co.).

railroad cars as well as for architectural and marine purposes.

Still another new class of alloys has been introduced lately for the manufacture of small products in automatic screw machines, for example, an alloy of the duralumin type (Alcoa No. 118). These new compositions yield short chips in screw machines and have machining qualities like free-cutting brass. The free-cutting aluminium alloys can be tooled in screw machines under practically the same conditions as the latter material. Such alloys are now supplied in the usual forms of screw-machine stock and are being used for numerous small parts. This development is expanding the market for aluminium in competition with both brass and steel.

Recent Applications

Aluminium and its alloys are employed in the United States by about 35 different industries, and the number of uses for these materials is now in excess of 2,000. The more important industries in which aluminium products are applied include the following: aircraft, automotive, building, chemical, cooking utensil, electrical, food, furniture, household appliance, machinery, paint, printing, radio, railroad, rubber, and steel. With regard to diversity of uses, aluminium (and its alloys in one form or another) is unsurpassed by any metal. Its range of applications extends from foil for packing to shapes for structural purposes. And it is employed in competition with such different materials as paper, cast iron, asbestos, and carbon black.

Among the more outstanding developments have been the use of strong aluminium alloys in building railroad cars, excavating and other heavy duty machinery, and certain structures in civil engineering. Besides, the application of both cast and wrought aluminium products in architecture has been especially notable. In the case of railroad equipment the construction of "all-aluminium" trains is a spectacular achievement. At present, such trains are run on regular schedules by several American railroads. The "Comet" of the New York, New Haven and Hartford Railroad, as illustrated in Fig. 3, is an example. Large freight cars have also been built mainly of aluminium alloys. Another application is for main and side rods of locomotives. About a year ago aluminium foil was specified for insulating a fleet of 2,700 fruit express cars.

The use of aluminium alloys in the construction of excavating and loading machinery is a recent innovation. A dragline boom 240 ft. long was built last year. Aluminium-alloy structural shapes make up 150 ft. of the length and steel shapes the remainder. In addition, machinery for handling coal and sulphur has been constructed with aluminium-alloy parts. Mine skips and a number of large travelling cranes have been built of strong alloy shapes and sections. Fig. 4 shows a Marion electric shovel (used for stripping coal) which is fitted with a dipper made mostly of aluminium alloys. This dipper is the largest ever built, having a capacity of 32 cubic yards.

Some new uses have been developed in civil engineering practice. One is for bulkheads. In the case of a roller-gate dam at Gallipolis, Ohio, a bulkhead consisting of seven units has been installed. Each unit weighs 28 tons and is 129 ft. long, 13 ft. wide, and 4 ft. 4 in. high. Aluminium-alloy bulkheads have also been constructed for the protection of buildings, particularly stores, in flood areas against damage by water. Another unusual application of wrought alloy material is in bridge construction, especially for the repair of floor structures. Such material has been applied lately for repairing the Smithfield Street bridge in Pittsburgh, Pa., and the Stratford Avenue bridge at Bridgeport, Conn. Still another new use is for portable bridges as employed in military operations.

A broadening field of use is in the construction of motor-bus and truck bodies, trailers, and transport tanks. In this connection a development of recent years is the manufacture of pressed chassis frames for various types of motor carriers. Heat-treatable alloys are employed for this purpose. Fig. 5 shows a Mack tractor-trailer unit with a capacity of 585 beer cases. Aluminium and strong alloy members were used for the body construction. The pay-load capacity of this vehicle is 15% greater for the same gross weight (within the legal limit) than of a corresponding unit with a body built of steel and wood. By way of contrast it is of interest to mention that aluminium wheelbarrows are being marketed. Late applications of castings include cylinder heads for passenger-car motors and various parts of Diesel engines.

Another expanding field of application for aluminium is in the brewing industry where it is used for fermentation and storage tanks. The aluminium beer barrel is a new product in the United States. Still another new use here

Fig. 6.—Tractor-trailer unit; aluminium body construction (Mack Trucks, Inc.).

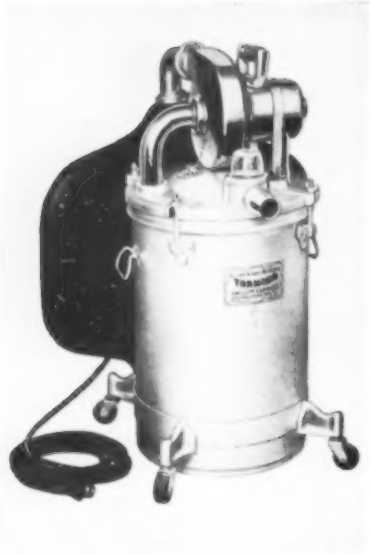


Fig. 7.—Portable industrial vacuum cleaner (Breuer Electric Mfg. Co.)

is as cans for packing tuna fish. The demand for aluminium furniture has increased rapidly during the last five years. Chairs and tables have been supplied to many hotels, restaurants, and bars. Beds, cribs, and other furniture are made especially for hospitals. Fig. 6 is a bottom view of a base for an office swivel-chair. This part was produced by die casting.

The output of aluminium closures and seals in the United States has grown very rapidly to more than two million a day. They are used to cap bottles and other containers for food, liquor, drugs, and cosmetics. Heavy foil hoods are employed for sealing milk in bottles. The demand for collapsible aluminium tubes has increased markedly.

Aluminium foil is being used in much greater quantities for wrapping confectionery, foods, and various products which need to be protected against air, moisture, or light. The consumption of aluminium paint has more than doubled over the last decade. It is now generally favoured for painting bridges and is being used considerably on wooden buildings as well as for priming mill lumber. Last year, three of the largest bridges in the country were painted with aluminium paint, namely, the Tri-Borough and George Washington in New York City and the San Francisco-Oakland Bay structure in California. The preparation of aluminium paste for pigment is a recent development. Paste is a more advantageous form than powder on several counts. Anodic coating by the Alumilite process is being applied to widely diversified products for protection against corrosion and also for decorative effects. Surfaces of equipment which liberate heat are treated by the Alzak method, for example, hair curlers and dryers.

Some of the applications mentioned above are, of course, not strictly new but have been coming into greater favour. Consumption of aluminium for most old established uses has been increasing during the last two or three years with the recovery from the industrial depression.

Trend of Market Expansion

In the United States the more important fields where the use of aluminium is now expanding considerably or may soon be greatly increased include the following: motor-buses and trucks, aircraft, railroad rolling stock, buildings, household equipment, industrial machinery, and food products including beverages.

The body work of nearly all buses now being built here consists mostly of aluminium materials. Street and interurban railway systems are generally moribund in the United States, and street cars have been supplanted widely by buses. This combination of conditions forecasts an expanding market for aluminium. With the trend towards high speeds and limitation of weight the use of aluminium in building trucks has increased substantially. The transport of freight, both short and long haul, by trucks has been extended very rapidly since the depression. Further expansion in the consumption of aluminium by manufacturers of motor trucks and trailers is expected. The use of strong light alloys for the construction of both transport and military airplanes is firmly established. Increased demand for aluminium from the aviation industry is conditioned mainly by its future growth. The potential use of aluminium by builders of railroad cars, both passenger and freight, is quite promising. Aluminium construction of cars is a feature of various streamlined passenger trains which have been built within the last few years. Also, the outlook for increased consumption in marine work is much improved.

Marked impetus has been given to the application of aluminium in construction by its use in a number of large buildings, notably the Rockefeller Centre group at New York City. Aluminium materials have found much favour in remodelling shop fronts, especially because of the attractive and corrosion-resistant finishes which are applied. Increased use is noted in the construction of apartment buildings and private dwellings, particularly for window frames but also for interior trim, railings, doors, hardware, and insect screens. Small houses of the prefabricated type have been insulated with aluminium foil. The consumption of aluminium in the manufacture of household wares and appliances is growing. These include the familiar cooking utensils, clothes- and dish-washing machines, vacuum cleaners, refrigerators, and decorative articles.

The use of aluminium materials for moving parts of machinery, mainly textile machines and equipment for wrapping packages, is increasing. Another growing market is in the manufacture of portable tools and apparatus. Fig. 7 shows the Breuer portable vacuum appliance for industrial cleaning. Due chiefly to the use of aluminium the total weight of this cleaner is only 40 lb.

With reference to equipment for breweries and dairies the application of aluminium in the United States has been laggard as compared with Europe. At present, however, it is being employed here in much greater degree than previously for fabricating such equipment. Good gains have also been made in the application for chemical equipment.

Finally, it may be remarked that much fundamental work has been done lately by the Aluminum Company of America with the object of ascertaining the information needed for the proper design of aluminium-alloy structures. This is expected to increase greatly the market for aluminium over the long term.

United States Bauxite Industry in 1937

The United States shipments of bauxite in 1937 were the highest recorded since 1923. The high rate of production reflected primarily the record output of virgin aluminium. The total shipments from United States mines was 418,000 long tons valued at $2,446,000, an increase of 12% in quantity and 11% in value over 1936. All the increase was credited to mines in Arkansas, shipments from Alabama and Georgia registering a slight decline.

During the first 11 months of 1937 bauxite imports increased 54% over the corresponding 1936 period (293,046 tons), and exports of bauxite and bauxite concentrates increased 48% over the 77,381 tons exported in the same period of 1936. Receipts from Surinam continued to advance, showing an increase of 73% over 1936, while imports from British Guiana remained practically the same. Yugoslavia and British India did not export any bauxite to the United States in 1937, but a small tonnage was received from Greece and France. Surinam accounted for 77% of the total imports from January to November, inclusive, 1937, as compared with 68 % in 1936, whereas the percentages from British Guiana were 18 and 27.

Of the 11 months' exports in 1937, 76,539 tons were bauxite and other aluminium ores, and 37,823 tons consisted of bauxite concentrates, alumina, etc. The respective tonnages for the corresponding period in 1936 were 50,247 and 27,134. In 1937 Canada took all the cruder materials and 28,175 tons of the bauxite concentrates, alumina, etc. The balance of the latter to Norway, Sweden and Japan.

THE ALUMINIUM INDUSTRY IN FRANCE

The Chambon dam as it appeared towards the end of 1935.

By
HENRY d'AUVIGNY
Directeur Commercial de la Société Aluminium Française

In contrast to most other producing countries France is fortunate in having bauxite mines, and refining and smelting plants situated in adjacent regions; further, her ore deposits are probably the largest and richest in the world. France has frequently been referred to as the cradle of the aluminium industry as a result of the work of her pioneers, and in this article it is shown that she still maintains the progressive spirit with which the industry is endowed.

FRANCE, the home country of Sainte-Claire-Deville, to whom we are indebted for the final evolution of industrial production of aluminium by chemical process, and of Héroult, whose electrolytical process for producing the metal is still being universally applied at the present day, owes a duty to herself to maintain the first place in the light metal industry in which she has been put by the work of these two scientists. She has not been found wanting. Nature moreover, has placed the country in a very favourable position and if it has been possible to refer to France as the "cradle of aluminium" this is not only due to the discoveries of Sainte-Claire-Deville and Héroult, but also to the fact that its subsoil was the first to supply the essential aluminium ore, namely Bauxite.

Production and Conversion of Aluminium in France

It is hardly necessary to recall that bauxite owes its name to the village of Baux in the Provence district, where the chemist Berthier discovered the first beds of ore, and which was to become the first centre of extraction of the mineral. If the deposits at Baux have at the present day lost their economic importance, the bauxite mines in the districts Var, Hérault and Bouches-du-Rhône keep France in a privileged position in this respect. Their yearly production, which is of the order of 500,000 to 600,000 tons, actually represents approximately one-third of world production and not only supplies the raw material for French aluminium production but also contributes extensively towards supplying foreign requirements. The treatment of bauxite with a view to extracting the aluminium required by the French electrolytic works is carried out near the deposits, the Gardanne and La Barasse works in the vicinity of Marseilles, Saint-Auben, in the Lower Alps, and Salindres in the Nimes District.

Electric energy, another important factor affecting the cost of aluminium is, as a rule, supplied by the torrents of the Alps and Pyrenees. Whereas the volume and regularity of the falls in the valleys of de Arve, the Arly, the Arc, de Romanche and the Durance in the Alps and in the rivers of the Pyrenees did not, a few years ago, allow of such constant working as might have been desirable, the great works carried out to control the water at La Bissorte and La Girotte in Savoy, at Le Sautet on the Drac, at Le Chambon on the Romanche, and the electric interlinkage recently completed between the various power stations, now assure the French aluminium works of an energy capacity with a regularity which the works abroad may well envy.

The drop in price which followed the introduction of the electrolytical process of manufacture soon called attention to the possibilities offered by aluminium, and several French Companies were formed to produce the metal. Their interests were gradually absorbed by two companies; the Compagnie de Produits Chimiques and Electrométallurgiques Alais, Froges and Camargue, and the Société d'Electro-Chimie, d'Electro-Metallurgie and des Aciéries Electriques d'Ugine, who are at present controlling the works at Chedde, Venthon, La Praz, Saint-Michel-de-Maurienne, Saint-Jean-de-Maurienne, Rioupéroux, les Clavaux, Prémont and l'Argentière in the Alps, Auzat, Beyrède and Sabart in the Pyrennees, the production of which is sold by the Société L'Aluminium Français, who operate as a common Sales Office for both Companies.

The diversity in scope for the application of aluminium, a material condition for the development of this industry, has been the result of research carried out in all countries with a view to reducing the cost, improving the conditions of manufacture and the quality of the metal, developing alloys endowed with higher properties than those of pure aluminium, perfect welding and plating methods, etc., and is attributable also to the efforts of manufacturing companies equipping their works with plant adapted for the treatment of new alloys and capable of supplying consumers with suitable products.

French industry has taken a substantial share in this scientific and technical work. With regard to the purity of the metal especially, reference should be made to the work in France which led to the perfecting of an electrolytical refining process by which a metal of 99·99% purity is obtained under industrial conditions. This process which represents a pronounced progress over that which enabled Hoopes to obtain metal of 99·9% purity in the United States in 1922, has been patented by the Cie Alais,

The Sautet dam, completed in 1935, the water surface at the level of 760 metres. In the centre the retaining wall and the new Sautet bridge. To the left the water intake constructions of the power house. On the left the flood discharge works which permits of clearing a flood volume of 1,400 cubic metres a second.

Froges and Camargue and is worked under licence in various countries. This metal, the chemical resistance of which is remarkable, has already met with useful applications, more especially in the industry of electrolytical condensers.

While the major stages in the improvement of light alloys are the discovery of Duralumin by Wilm in 1906 in Germany, and of Alpa in the United States by Pacz in 1921, the French engineers have not remained alien to the development which have materialised in this field. In addition to their contribution towards the improvements in the preparation and treatment of the various groups of alloys, we may cite, as the direct result of their work, the improvement to Almelec, an alloy for electrical conductors ; of AP. 33, a foundry alloy for thermal treatment ; the alloys for decoration, such as the 41.SM. and so forth.

It is reasonable in this connection also to make reference to the work by Paul Odam, who in 1904 discovered the flux which permitted the autogenous welding of aluminium, a discovery of capital importance which opened up an extremely wide scope of application for light metal ; also to the very recent ones of Sciaky who has bestowed upon the light alloy working industries an electric welding machine which is one of the most highly perfected at present in existence.

While the improvements were being brought about in the laboratory, the French manufacturing industries have not remained idle but have equipped themselves to follow up the progress in practice and to fulfil the constantly growing requirements of the users. The small melting crucibles gradually gave way to modern plants in which furnaces of 8 to 10 tons capacity are not unusual but sometimes actually reach a size of 15 tons, such as in the works of the Duralumin Company ; forging equipment was adapted to the new requirements and at the present time propellers and crankcases for aircraft engines are being forged with hammers, the ram weight of which may reach 40 tons. The number of rolling mills specialising in the treatment of aluminium and its alloys multiplied and among the most important may be cited the plant of the Duralumin Company at Rive-de-Gier, Faremoutiers and Le Bourget, of the French Aluminium Company in Chambéry, of the Compagnie Française des Métaux in Castels Arrazin and in St. Denis, of the Havre Wire Drawing and Rolling Mills in Dijon and Pont-de-Chéruy, of the Forges de Crans in Cran-Gévrier ; and last but not least, the plant of the Compagnie Générale d' Electrométallurgie de Dives, of the Etablissements Japy, the Etablissements Schneider, etc. Due to the modern equipment of these works, which cover the needs of the French market, a range of products is being currently produced from sheets of 3 metres width and a few millimetres in thickness down to aluminium foil of $\frac{1}{100}$ mm. gauge and 600 mm. width.

The possibility of extruding light alloys under presses, to obtain a variety of shapes not possible by rolling, ensures a further advantage to light alloys over heavy metals. Here again the progress made by French plant has followed the evolution of requirements ; whereas 20 years ago the capacity of the presses did not exceed 1,000 tons, thus limiting the weight of the billets which could be extruded to some 25 kilos and the diameter of the rods obtained to 80 mm., it is now possible, by means of the presses, such as that of 4,500 tons which the Duralumin Company have available, to produce bars of 300 mm. diameter, having a weight up to 400 kilos.

The rapid development of the electrical industry was bound to involve on parallel lines, the improvement of the equipment installed in the works specialising in the production of wires and cables. As a matter of fact, the works of the Havre Wire Drawing and Rolling Mills at Le Havre, of the Compagnie Générale d'Electrométallurgie in Vitry, of the Compagnie Française des Métaux in Givet, of the rolling mills and cable works in Lens, of the wire drawing and cable works in Bourg, have modern plant available which enables them to compete in quality with the best foreign workers.

Aluminium Applications in France

While abundant raw material is available in France, with well equipped works for production and conversion, the country has found an outlet in its home market for the greater part of its production. It is not possible in this brief article to examine in detail the various applications in which aluminium has gained prominence, but it is of interest to analyse, briefly, the distribution of uses and to set forth some of the more characteristic practical applications developed in the various fields.

Saint-Jean-de-Maurienne works (Compagnie Alais, Froges and Camargue).

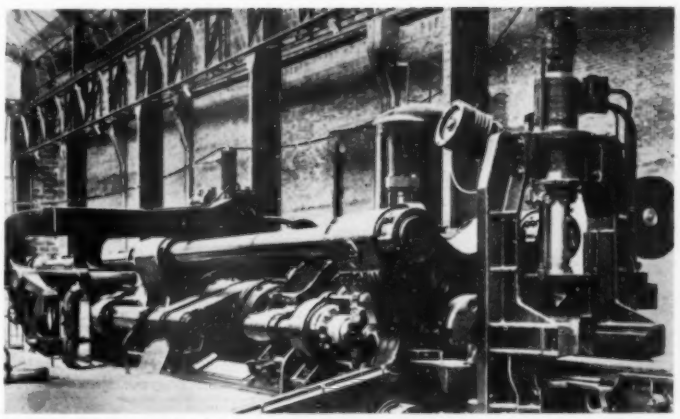
Transport Industries

The part taken by transport in French consumption has increased appreciably during these latter years and it is estimated that the transport industry represents near to half the total consumption of the country. It is in France that aircraft manufacturers employed light alloys for the construction of aircraft on an extensive scale; the chief stages in this development are the appearance in 1916 of the Breguet XIV airplane, comprising fuselage tubes and engine supports made of aluminium alloys and of the Breguet XIX which was the aircraft made entirely of Duralumin, turned out in 1924, a design which was soon copied by numerous makers abroad.

It is only after the Naval Agreement of Washington in 1921 that light alloys met with extensive application in the French navy, but it may be said that as soon as aluminium appeared on the market, the interest in weight reduction promoted had been turned into practical application by the French naval engineers and one of them, M. Guilloux, had actually constructed a torpedo boat of aluminium in 1892[1]. The mercantile marine, less interested in keeping down weight, but in quest of incombustible material, also called upon light alloys, and the provision of six cabins made of aluminium on the ocean liner *Normandie* has proved that the use of this metal is perfectly compatible with the requirements in this form of construction.

In the sphere of railway engineering, France certainly occupies first place in Europe in the matter of light alloy application. It was the 23 coaches on the main lines of the Northern Railway Company, each comprising approximately 3 tons of aluminium, which provided the first major application in 1923. This example was soon followed by the 380 carriages for the suburban lines of the Government Railway system, with 1,500 kilos of aluminium, and the double-decker carriages for the same railway system, which contain 5 tons of aluminium. Mention may also be made of the recent construction of the articulated train of the Northern Railways, wholly welded and made of aluminium alloy containing 7% magnesium, and leading to a reduction in dead weight of 37·5% compared with steel construction (275 kilos per seat as against 440 kilos). But it is chiefly upon the appearance of rail-cars, which have been greatly developed in France, that the use of light alloys has been speeded up in rolling stock production, in so far as this material has been used for the whole of the construction; body and underframe (Compagnie des Entreprises Industrielles Charentaises) or, alternatively, limited to the construction of the bodywork (Michelines) or even the panelling only of a steel frame (Renault).

[1] *de Biran: Evolution of Aluminium applications during the last fifty years* (*Aluminium Review No.* 84—1936).



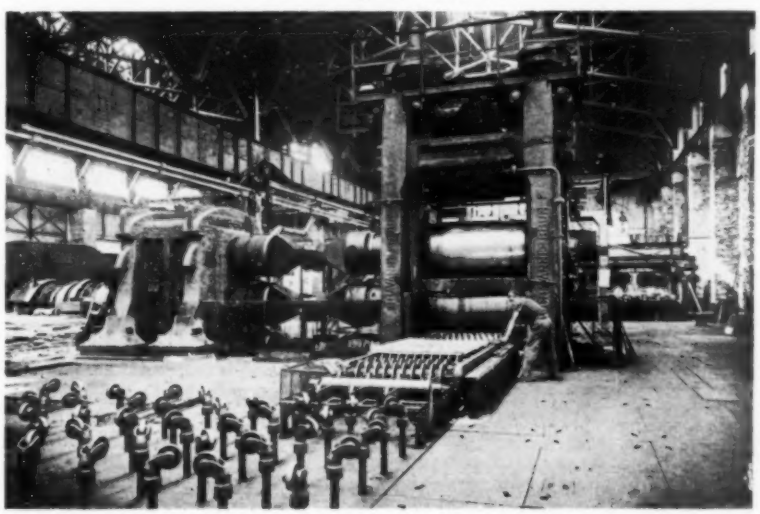
Extruding press for bars, tubes, sections of light alloy, of 4,500 tons capacity (Couzon works of the Duralumin Company).

The motor industry in France has proved to be one of the first and most important for aluminium consumption; since 1905 aluminium crankcases have regularly been cast and in 1920 automobile construction represented approximately 75% of the market outlet for aluminium. Although the multiplication of further applications since that time has reduced this proportion to 20 to 25%, the French motor industry is still a large consumer of light alloys. The use of aluminium pistons has become general (90% of French cars have been equipped with such since 1928), and that of cylinder heads has developed rapidly; aluminium has also secured its position in engine block units, more especially for Diesel engines on lorries and for the coach work of many types of cars (touring, public transport, lorries).

Electrical Industries

France was not the first country to make electric conductors of aluminium. Yet it may boast of having a line still in commission which was laid in 1905 between Grenoble and Saint-Etienne, consisting of pure aluminium cables. It was only during the period 1910 to 1914, however, that the use of aluminium or aluminium-steel conductors gained real importance. The work of a French engineer, M. Dusaugey, who was the first to adapt the methods of calculus laid down for copper conductors[2] equally to aluminium leads, is responsible in appreciable measure for the rapid development of aluminium in this field. The French Government grid, established between 1921-1923 in the areas devastated during the war, made a singular call upon aluminium conductors and also in the construction of the master grid at 220,000 volts which was erected a few years later, for which steel cored aluminium cables were considered best fitted. At the beginning of 1937, aluminium lines covered France by a vast network of more than 55,000 km. of conductors representing 35,000 tons of aluminium.

Three-high hot roughing rolling mill for rolling light alloys. The cylinders are of 1.10 m. diameter and 2 m. length (Couzon works of the Duralumin Co.).



The Chemical and Foodstuffs Industries

With some 30,000 to 40,000 tons of aluminium used in these industries the development is appreciable. But the diversity of present applications would

[2] *Dusaugey: Electric Conductors of Aluminium and Aluminium Steel*, 1912.

Articulated train of the Northern Railways, comprising three coupled coaches having bodywork joined by arc welding and made entirely of light alloy (Duralinox). The saving in weight has reduced the number of bogies without overloading the axles. The weight reduction is 37.5% compared with similar carriages of steel.

demand a space which we cannot here afford. Household utensils play the major part in this tonnage; also, mention should be made of the vast use of this metal in the brewing and dairy enterprises. As far as the food-stuff industry is concerned, and its use in the nitric acid industry, in the manufacture and packing of glues, gelatines, varnish, etc., the advantages of aluminium are daily gaining increasing interest.

While the jewellery and silversmith trades were the first consumers of aluminium, towards 1860, when it was regarded as a precious metal, other decorative industries have not failed to find a wide use for the numerous aluminium alloys now available at comparatively low cost. At the Decorative Art Exhibition in Paris in 1925 the welcome afforded aluminium was such that it has enjoyed a reputation among architects and decorators since that time. During these latter years the uses of the metal have multiplied in the shop-fitting, apartment fitting and furnishing lines, etc., and the 1937 Paris exhibition emphasised this tendency which places aluminium in the forefront of decorative metals.

View of framework of Amilcar compound 1938 car in course of assembly. Part of the body which comprises two side-frame panels, a cowling and a front cross-beam to support the engine, is made of treated Alpax.

As far as production is concerned, we may affirm that one of the chief characteristics of the French aluminium industry is that of being a perfectly balanced industry. Endowed with raw material and electric energy, due to the harnessing of its water resources, the French aluminium works provide for the requirements of the home market as well as for export. With regard to manufacturing works, large as they are at the present, they are fitting up new plant intended to meet the increasing demands of users, whose number grows from year to year, and the place occupied by this industry in our national economy shows every likelihood of developing in the future in an appreciable and constant manner.

Edgar Allen and Co. Ltd. have received some interesting contracts for machinery. These include two large rotary dryers, mechanical stirring gear for a large petroleum company and a tube mill and feed table for the Queensland Cement and Lime Co., Ltd., Australia.

Recent Metallurgical Developments in Aluminium and its Alloys

Continued from page 133).

of aluminium alloy bearings containing lead or graphite, or for the production of finished components for high temperature service in aluminium containing ferrous alloys that are difficult to fabricate in the normal manner.

Cheaper Production Methods

The direct rolling of strip from molten aluminium held in a reservoir above a pair of rolls seems at first sight a rather fantastic proposition, but more than one experimental plant, operating on the Hazelett principle, has been installed in America and their performance will be watched with close attention. The potential economies are enormous, for it is possible to produce, in one operation, strip 0·12in. thick, and of approximately half-hard temper,[4] which in the ordinary way would necessitate casting of a rolling slab, reheating, and hot- and cold-rolling, with possibly, an intermediate anneal. Of the light metals only pure aluminium seems to have been tried so far, but there would not appear to be any reason why at any rate the simpler aluminium alloys should present much additional difficulty. It has been demonstrated that the quality of the material from experimental runs can be extremely satisfactory, but it remains to be seen whether the very great practical difficulties connected with continuous production on a commercial scale can be successfully overcome.

The rolling of structural shapes does not compare favourably with extrusion, so long as the overall dimensions of the section are relatively small and the lengths required not great enough to bring the total weight of a piece up to the capacity of the press, far more intricate sections can be produced by extrusion than by rolling, and the cost of dies is many times lower than that of rolls for forming. Present extrusion presses range up to about 5,000 tons rating, but the weight of the billets for them does not exceed about 300 lb., probably less in the stronger alloys. The weight of extruded sections already ranges up to six or seven pounds per foot run; if the dimensions of aircraft continue to increase at the present rate, and if aluminium alloys are to be considered seriously for the heavier types of engineering, the demand for larger sections may reach a point where rolling is more economic than extrusion. In this connection, it is interesting to note that a rolling mill for structural shapes in aluminium alloys was constructed in America about ten years ago, in which it has proved possible to roll sections in heat-treatable alloys up to 90 ft. in length from billets up to 3,000 lb. in weight. So far, however, the demand has not been such as to justify the enormous expense involved and it seems probable that such an installation is still somewhat ahead of its time.

Canada's Aluminium Exports

Canada's exports of aluminium bars, blocks, etc., during the twelve months ended November 30, totalled 929,538 cwts., valued at $16,735,198, as compared with 595,940 cwts. ($11,166,929) in the previous year. Exports to the United advanced last year from 411,843 cwts., ($7,954,697) to 444,074 cwts. ($8,530,120).

[4] J. W. Lippert, *Iron Age* 15/10/46.

The Development of the Aluminium Industry in Switzerland

By
Professor Dr. A. VON ZEERLEDER, A.I.A.G.

The initial production of aluminium in Europe on a commercial basis commenced in Switzerland, and the review of developments in that country is particularly interesting, showing as it does the gradual progress in furnace design and great foresight in meeting the needs of possible consumers of the metal.

THE youngest metal used in large quantities in industry is aluminium. It was first obtained in 1825 by Oersted, and a little later by Wöhler, by reducing, chemically, aluminium chloride with potassium. St. Claire Deville developed on this basis his process, by which he produced, from 1854 to 1890, about 200 tons of aluminium: but the price of the metal was so high, in spite of considerable improvements in the process, that it could not find any large application in industry. Only when Héroult and, a little later, Hall patented, in 1886, the electrochemical process did it become possible to produce aluminium at a price sufficiently low to enable developments in applications. This process, consisting in the reduction by means of electric current of alumina dissolved in fused cryolite, is in principle the same as is applied to-day.

As Héroult did not find recognition for his invention in France he signed a contract for its development with the "Schweizerische Metallurgische Gesellschaft" (Swiss Metallurgical Company), which had purchased the former ironworks at the Falls of the Rhine, near Schaffhausen (Fig. 1). By 1888 experiments had proceeded to such an extent that the research company, with a share capital of 200,000 Swiss francs, was converted, with the co-operation of other enterprises, into the Aluminium-Industrie-Aktien-Gesellschaft (A.I.A.G.), Neuhausen, with a share capital of 10 million Swiss francs. The reproduction of the trade mark in Fig. 2 shows, in a symbolic manner, the beginning of a new light-metal age, which the founders of the A.I.A.G. foresaw from further developments in the production process. As the A.I.A.G., the oldest European aluminium company, can now look back to an existence of 50 years, it is a good opportunity to describe in some detail the evolution of the electrolysis of aluminium.

Although the first patents of Héroult related expressly to the electrolytic production of pure aluminium, the inventor applied himself first to the production of aluminium-bronze in a modified furnace, following the advice of the French manufacturer, Péchiney. This first furnace, used in 1888 at Neuhausen, is reproduced on Fig. 3, which also shows the development of aluminium furnaces at the works of the A.I.A.G. from 1888 to the present time.

Kiliani, one of the managers of the A.I.A.G., successfully persuaded Héroult to concentrate on the production of pure aluminium, and developed, in 1889, a modified furnace for this purpose, which Héroult adopted when he installed, in 1889-1890, the first French aluminium plant at Froges. Whilst in the Kiliani furnace the electrodes turned on their axes, and the furnace hearth was stationary, at Froges Héroult used stationary electrodes and a rotating hearth until he found by chance, through an interruption of the mechanism, that the furnace worked just as well with a stationary hearth.

The high current consumption of these first aluminium furnaces was chiefly due to small-sectioned anodes. The discovery of this fact led Héroult to quadruple the section of the electrodes for the furnace he developed during the years 1892 and 1893, the current intensity being maintained at 4,000 to 6,000 amps.; in that way the efficiency

Fig. 1.—The Rhine Falls with the former hammer mill (Left)

of the furnace was considerably improved. The difficulties of obtaining larger carbon electrodes compelled Neuhausen to build special furnaces in 1893 with a larger number of small, round electrodes, the total section of which corresponded to the density of 1·5 amps./cm.² established by Héroult.

To avoid difficulties in the making of the electrodes Neuhausen, in 1894, built its own electrode factory, and returned to larger square electrodes, which were used in 1895 for the first time. The 8,000-amps. furnace was carefully developed and improved in all details to the highest efficiency, so that, with a current consumption of 24 kw.-hours for 1 kilog. of aluminium, a result was attained which was very satisfactory for that time. This furnace was in use until 1920, when a new development of the aluminium electrolysis began. Together with the increase of the current densities, which was facilitated especially later on, by the introduction of the mercury-arc rectifiers, even larger furnace units were built. At this time further noticeable improvements in the current consumption and, simultaneously, savings in wages and local needs were obtained. By doubling the 8,000-amps. baths to 16,000 amps. in 1920, the company developed the furnace shown in Fig. 3.

Fig. 2.—Trade mark of Aluminium Industrie Aktion Gesellschaft.

As long as no electrodes were available other than the baked electrodes, there was no incentive to build larger furnaces because of the increasing number of the electrodes, but the invention of the continuous self-baking Söderberg electrode opened the way for the further development of aluminium electrolysis. It lasted, indeed, until the Söderberg electrode was developed to such an extent that contamination of the aluminium by iron from the armatures of the electrodes could be avoided. To-day, with Söderberg electrodes, it is possible to attain just as high purity of the

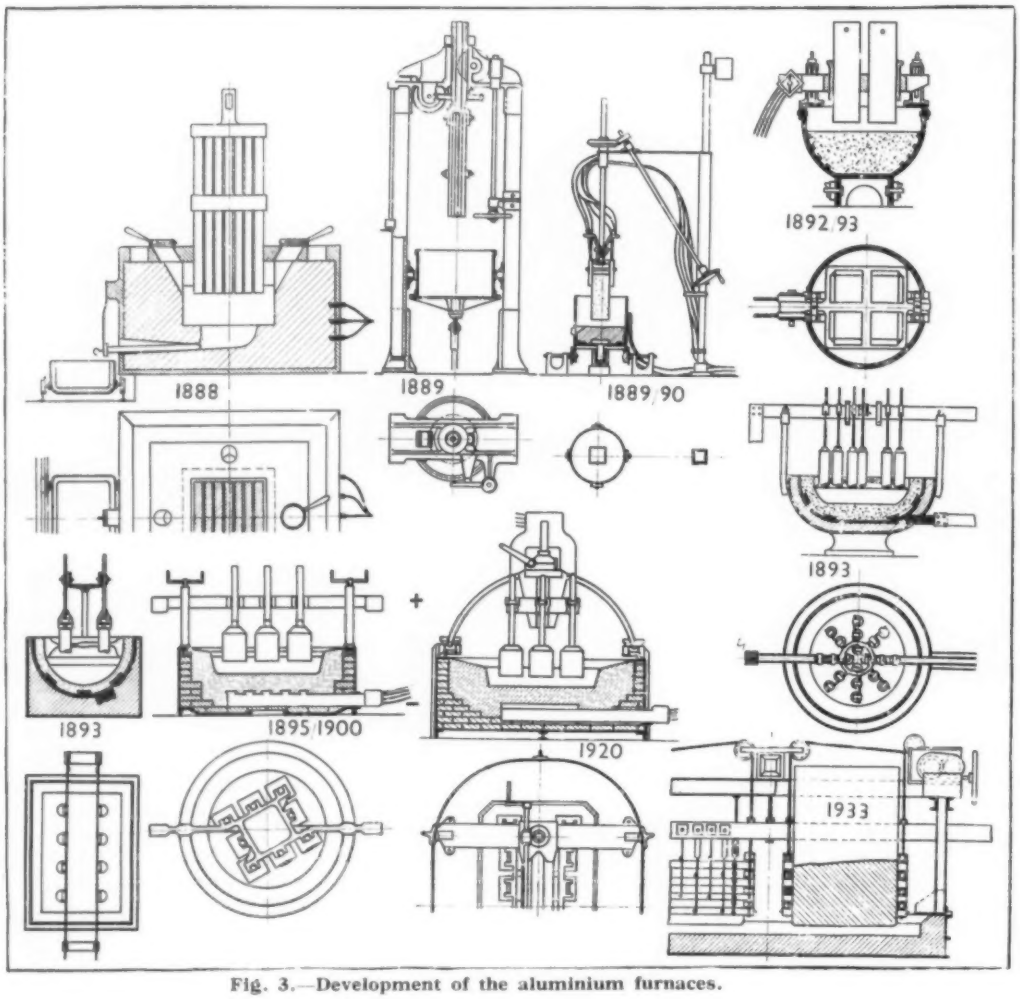


Fig. 3.—Development of the aluminium furnaces.

aluminium as with the baked electrodes. There are practically no more limits to the current intensity when one or two Söderberg electrodes are used. In 1933 Söderberg furnaces were developed with about 30,000 amps., and to-day, in some plants, there are furnaces working with 45,000 to 50,000 amps., and it was possible to reduce the current consumption down to 18 kw.-hours for 1 kilog. of metal, and even less.

High-Purity Aluminium

Whilst the principle of aluminium electrolysis has not changed during the last 50 years, the last decade has witnessed success in solving the problem of the electrolytic refining of the aluminium (which problem had been studied by Betts and Hoopes), so that in addition to aluminium with a purity up to 99·8%, produced by normal electrolysis, to-day it is possible to produce, by the refining process, an especially pure aluminium with an aluminium percentage of 99·99. Besides the processes of the Aluminium Company of America and of the French company, Alais, Froges et Camargue, the A.I.A.G. also developed its own refining process. The latter is based on the three-layers principle established by Betts.

In this process the aluminium to be refined, made heavier chiefly by means of copper, lies on the bottom of the refining cell (Fig. 4). The lighter electrolyte, made from fluorides of sodium, magnesium or calcium and barium, and having a melting point of about 700° C., floats upon it, but because of the barium content the electrolyte is heavier than pure aluminium, so that the purified metal, which forms the third layer, floats on the electrolyte. This refined metal is characterised by a particularly high resistance to corrosion, high electric conductivity and ductility. In view of its high resistance to corrosion it is used especially in the chemical and food industries as foil, or as a plating layer on ordinary aluminium, or on alloys of high strength, in the construction of apparatus, and in the manufacture of electrolytic condensers. On the introduction of refined aluminium its advantages were readily appreciated, and to-day the demand is increasing steadily.

Aluminium Alloys

During the first years of the industry attention was directed to the working of the aluminium, and in 1892 Neuhausen built its own rolling mill, to supply aluminium sheets; work also proceeded in the manufacture of aluminium alloys, the physical properties of which were thoroughly investigated by Professor Tetmayer, of the Swiss Testing Laboratory in Zürich. Until 1920 only a few alloys had been developed by private and official research laboratories. The increase in the production of aluminium, due largely to the World War, led to the further investigation and development of aluminium alloys, and Neuhausen enlarged its research laboratories and subsequently developed a whole series of alloys, brief data on which are given in Table 1.

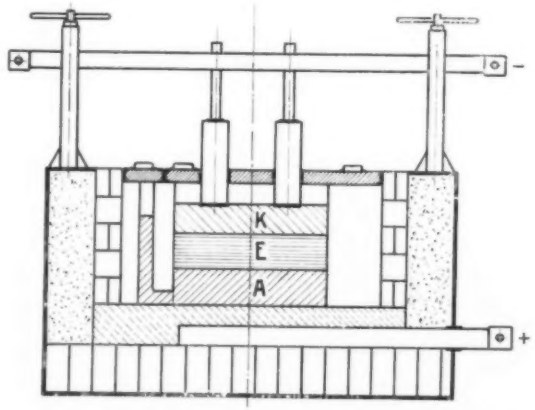


Fig. 4.—Aluminium refining cell (schematic).

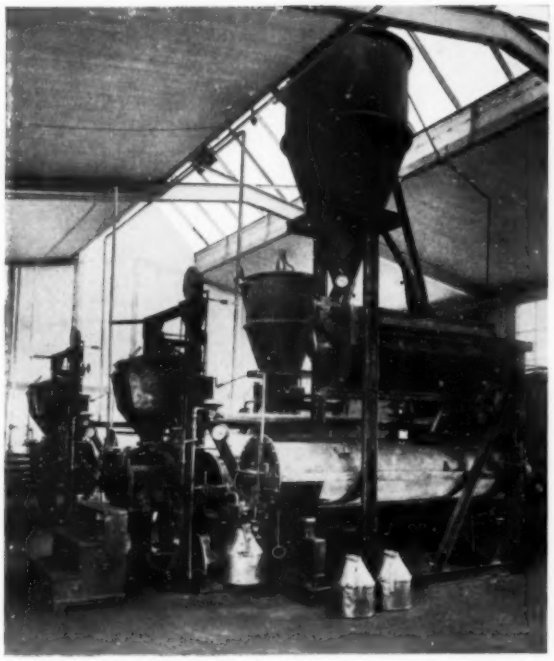


Fig. 5.—Aluminium-powder plant Hametag.

TABLE 1.

Alloy.	Composition.						Mechanical Properties.		
	Si.	Fe.	Cu.	Mg.	Mn.	Ti.	Yield Point, kg/mm.²	Tensile strength, kg/mm.²	Elongation %
Avional, D	0·5*	0·3*	3·8	0·55	0·5	—	24—30	38—44	22—16
„ S	0·5*	0·3*	4·4	1·0	0·5	—	32—38	46—50	18—14
Anticorodal, A ..	1·0	0·3*	—	0·7	0·7	—	16—21	25—29	22—18
„ B ..	1·0	0·3*	—	0·7	0·7	—	27—30	32—36	14—10
Aldrey	0·5	0·2*	—	0·45	—	—	27—31	30—35	9—5
Aluman (soft) ...	0·3*	0·3*	0·1*	—	1·5	—	4·5—6	10—12	40—30
Peraluman, 2	0·3*	0·3*	0·1*	2	1·4	—	10—15	22—25	20—16
„ 5	0·3*	0·3*	—	5	0·5	0·1	12—15	26—30	25—20
„ 7	0·2*	0·4*	0·1*	7	0·5	0·1	15—20	30—34	24—18
Alufont II	2·5	0·6*	4	0·2	0·6	0·15			
Chill cast							28—32	31—36	1·5—0·8
Sand cast							26—30	30—34	1·5—0·8
Anticorodal	5	0·45*	0·1*	0·7	0·7	0·15			
Chill cast							24—29	25—30	2—1
Sand cast							22—28	23—30	1·5—1·0

* = maximum.

The alloy "Anticorodal" may be mentioned first: this is an Al-Mg-Si-Mn alloy with 1% of silicon and 0·7% each of magnesium and manganese, which obtains its high mechanical properties, after rolling, extruding or forging, by a heat-treatment consisting of a solution treatment, followed by a quenching and a final age-hardening at 150° C. In addition to its good mechanical properties,

Fig. 6.—Rolling mills in the Rhone Valley.

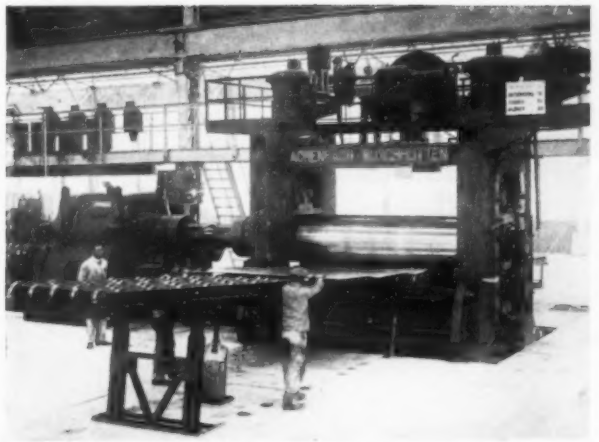


Fig. 7.—Three-high break-down rolling mill.

the most remarkable property of this alloy is a high resistance to corrosion, which represented a considerable improvement on the Duralumin alloys invented many years earlier. Whilst Anticorodal has a relatively low electrical conductibility, the alloy "Aldrey" has the particularly high electric conductivity of 31—33 $\frac{m}{ohm \cdot mm^2}$: it contains about 0·5% each of Si and Mg, but compared to Anticorodal it has a different heat-treatment, the solution treatment being carried out on the 15-mm. thick rolled wire before the cold drawing to the final diameter takes place. This cold working causes considerable hardening, which is eliminated by a subsequent tempering at 150° C. for 8 hours, by which the electric conductivity is simultaneously increased. The research laboratories also

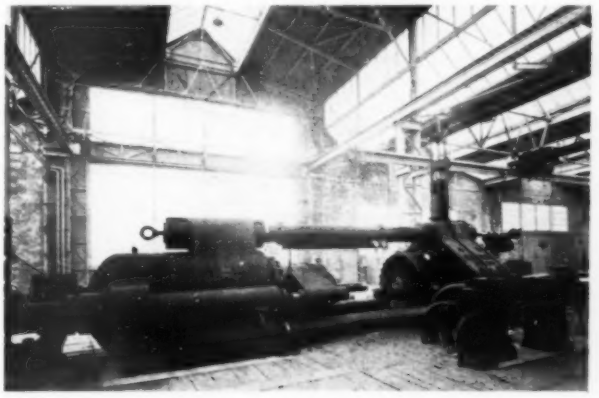


Fig. 8.—Extrusion press for aluminium alloys.

contributed to the development of the Duralumin-type alloy "Avional," which was improved in strength and working properties by the addition of further constituents. Other alloys, including those with 2 to 10% Mg, casting as well as wrought alloys, were developed.

Aluminium Powder

The making of aluminium powder was also intensively produced in Switzerland. The first modern plant

Fig. 9.—Alpine 'bus of the Swiss postal lines.

operating on the Hametag method, in which, instead of the usual stampers and rammers, air-tight ball mills filled with a neutral gas are used (Fig. 5), was started in Switzerland.

Rolling Mills and Extrusion Works

Although the erection of a rolling mill for the working of aluminium was necessary in 1892, about 1925 it was recognised that rolling mills and extrusion presses for aluminium alloys required to be larger and heavier machines than those for pure aluminium. It was decided to build the works, shown in Fig. 6, in which were installed the first European heavy three-high rolling mill and extrusion press for aluminium alloys. The mill (shown in Fig. 7) carries rolls 11 ft. 2 in. long and 3 ft. diameter, and rolls aluminium alloy sheets up to 10 ft. wide and 40 ft. long, while the press (Fig. 8) is equipped with a compressed air accumulator having a capacity of 3,000 tons pressure. Although larger machines are erected to-day in other works, the fact that 10 years ago machines of these dimensions were chosen for the working of aluminium alloys is evidence of progress by this Company.

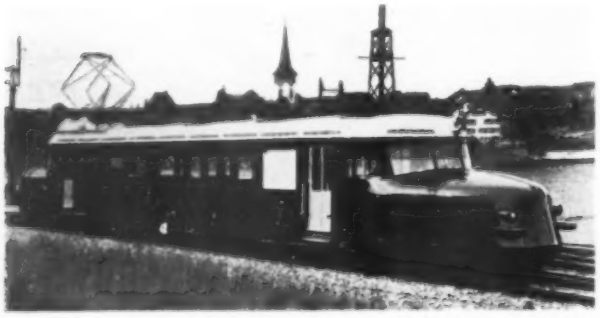


Fig. 10.—Light railcar "Red Arrow" of the Swiss Federal Railways.

Applications

In addition to the recognised applications of aluminium in many branches of industry, such as in motor and air- craft construction, efforts were

Fig. 13.—Milk churns made from Anticorodal.

No. 11 — Cabin of the air cable railway Beckenried-Klewenalp.

concentrated on further fields of application. The use of aluminium for motor-car body work and the construction of road transport vehicles was increased. To-day, hundreds of postal cars and buses with light-metal coaches are in use in Switzerland ; they are found very suitable, as is proved by the Swiss Alpine lines, where cars are subjected to the highest stresses on mountain roads (Fig. 9). The next step was the introduction of aluminium alloys in the rolling stock of railways. In this case also the advantages of the metal could not be overlooked, and the use of light railway cars, shown in Fig. 10, has gradually increased. Numerous suspended passenger cars which join our high peaks, with their wonderful views to the valleys, make use of Anticorodal cabins, as shown by a cabin of the Klewenalp Railway in Fig. 11, thereby increasing the useful load.

The corrosion-resistant alloy Anticorodal also began to be applied in the steamers on our numerous lakes. Used principally for the superstructure, as in Fig. 12, the stability of the ships is considerably improved. The enumeration of the new fields of application for aluminium would be incomplete without mentioning the food industries, especially the dairy industry, which is particularly well developed in Switzerland. In this industry the use of light metals is applied principally to the manufacture of milk cans (Fig. 13), which are used to convey milk often over great distances. Besides a considerable saving of weight in comparison with the tinned iron milk can, the light metal

(*Continued on page* 172)

Fig. 12.—Motor-boat "Mythen" of the Lake of Lucerne.

Aluminium and Its Applications

A Review of British Progress

BY A SPECIAL CONTRIBUTOR

IF one seeks for the reasons which have been responsible for the great development of the aluminium industry, they are to be found largely in the inherent properties of the metal itself and its ready adaptability to industrial requirements. Yet, it need hardly be said, each incursion into new fields of industrial application has been preceded by much circumspection and careful analysis of the problems to be encountered, and many exhaustive tests to determine the precise aluminium alloy most suited to the work in hand. To-day, there are but few, if any, industries in which aluminium and its alloys, in one way or another, do not play their part.

In this article it is proposed, after making some general observations in regard to castings and forgings, to show some of the varied applications of aluminium alloys in the United Kingdom for modern industrial purposes. Space will permit of only a limited description of these applications. Those who would like to examine the subject in greater detail would be well advised to consult the Aluminium Information Bureau which has recently been established at Bush House, London. This bureau provides the advice of experienced technical engineers on all problems involving the use of light alloys.

Castings

Aluminium in its pure metallic state does not possess good foundry characteristics, and in castings its mechanical properties are low. In its pure state, the metal is used, generally speaking, only for those purposes where electrical conductivity or its chemical properties are of paramount importance. Invariably, however, when aluminium is used in castings it is alloyed with small percentages of other elements such as silicon, copper, magnesium and nickel. The addition of carefully controlled small quantities of these elements improves the foundry characteristics and the mechanical properties of the castings, and the mechanical properties may be still further enhanced by suitable heat treatment.

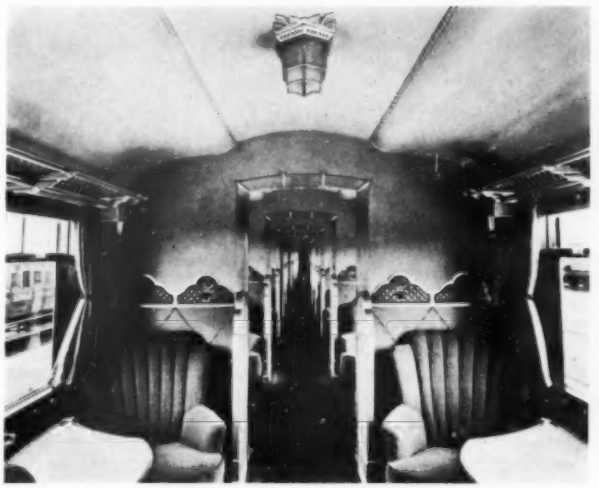
The useful characteristics of aluminium alloy castings lie in their light weight, ease of production both in sand and chill moulds, high strength (particularly in the heat-treated alloys), excellent corrosion-resistance, good finish and machining qualities and high thermal conductivity. Castings are available either as sand or gravity-die castings in a wide range of alloys to the majority of British Standard, Air Ministry and Admiralty specifications.

The choice of the best alloy and the decision as to whether sand or gravity-die castings are desirable can be based only on a knowledge of the casting itself and the conditions in which it will be used and the quantity required. A large number of casting alloys attain their maximum physical properties after heat-treatment, by the variation of which it is possible to produce from the same alloy different combinations of mechanical properties.

Forgings

Aluminium forgings are finding increasing use for industrial purposes by reason of the wide range of desirable characteristics with which the material may be invested by skilful workmanship. The prime factors responsible for the development of aluminium forgings are :—

1. High strength per unit weight.
2. High strength per unit area.
3. Resistance to corrosion.
4. High thermal conductivity.



Courtesy of Sir Nigel Gresley, Chief Mech. Eng., L.N.E.R.

Interior of 1st class coach on the L.N.E.R. " Coronation " express ; the metal work comprising extrusions and castings in aluminium alloys and pure aluminium sheet.

The highest mechanical properties can be secured by the use of forgings, and the heat-treatment processes involved are relatively simple, whilst they result in uniform and dependable products. Forgings are to be recommended for all applications where the highest mechanical properties and accuracy of form are primary requirements.

Aluminium and Aircraft

The importance of lightness of materials used in aircraft construction needs no emphasis. Extensive research and development work have made available strong aluminium alloys for structural shapes capable of withstanding the most exacting conditions. Spars, struts, ribs and longerons are now being made of heat-treated light aluminium alloys, which have also been found to meet the properties required in the skin material of stressed skin structures.

Many new alloys of high proof stress are now available in the form of sheet, plate, tubing, extruded shapes, bar, etc.,

Double decker bus, in which the panelling is of aluminium.

Courtesy of H. V. Burlingham Ltd.

Veteran Thornycroft with 250,000 miles to its credit fitted with an aluminium alloy body.

and are employed in the fabrication of spar assemblies, cowlings, rudder bars, control arms, brackets, bearings, landing gear and the like. Another application is in the forging of propeller blades. Not only does the use of an aluminium alloy result in increased strength, durability, and absence of warping, but in the event of the blade becoming bent it is capable of being straightened whereas, under similar circumstances a wooden blade would become useless. Again, in aero engine design the high tensile aluminium alloys are playing an increasingly important part.

Alloys, specially developed for use at elevated temperatures, are extensively used for aircraft pistons, cylinder heads, crank cases, and for a multitude of other applications where ease of machining and good heat conductivity are of advantage.

Aluminium in Motor Transport

In the last few years there have appeared many restrictive regulations regarding the unladen weight of motor vehicles. This factor, and the methods of calculation for taxation purposes, make the ratio of high pay load to low unladen tare of major importance in the construction of motor bodies; hence the widespread adoption of the aluminium alloy construction by which a great saving of "dead-weight" can be effected. In addition a vehicle is produced which will stand up to far more punishment than would steel or wood without breaking, and costs of structural maintenance and cost of painting are lessened.

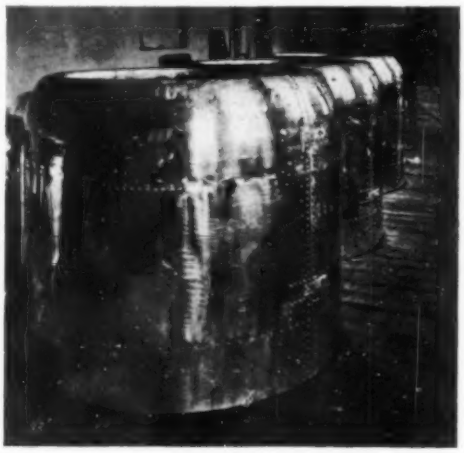
A 5 cub. yd. end tipping body on a Thornycroft "Sturdy" chassis constructed entirely of Duralumin.

Courtesy of Duralumin Eng. Co. Ltd.

The aluminium producers provide body builders with a wide range of grades of material from which the constructor may select an alloy to meet his requirements at a price dictated by the type of work in hand. Omnibus and trolley 'bus bodies are now largely panelled in aluminium, while in the case of a Birmingham Corporation tramcar using aluminium alloys, there was a saving in weight of as much as 3 tons 3 cwt. The adoption of aluminium alloy castings in vehicle construction has resulted, in many cases, in additional saving of weight. Such castings are supplied in a wide range of alloys, each having characteristics suitable for a variety of purposes.

An aluminium body may cost 70 to 100% more than a wooden one, according to the type of construction used. This factor of initial cost may appear a deterrent, but experience has amply demonstrated that increased pay load, economies in various ways outlined above, and the high scrap value of the metal contributing to eventual replacement cost, prove the economy of aluminium construction, even when comparative figures for so short a period as three years are examined.

Aluminium cowlings as used in aircraft.



Courtesy of the Northern Aircraft Products and Eng. Co.

By judicious selection of aluminium alloys, it is possible to construct an underframe to carry a load of 6 tons, yet weighing not more than 170 lb., which is a reduction of up to 50% as compared with the usual composite timber body. Similarly, aluminium alloy-constructed floors for goods vehicles reduce maintenance costs by reason of their ability to withstand impact, and additional economy is effected by the use of aluminium alloys for side and tail boards. Vehicles constructed from such alloys have been kept in service after accidents which would have disabled vehicles of steel or wood.

Aluminium alloy containers are clearly of importance in the transport of foodstuffs, not only by reason of savings on freight, but also because any possible contamination of foodstuffs is prevented by their use. Tanks and containers of aluminium are invaluable also for the carriage of many chemicals by reason of the chemical inactivity of the metal; moreover, the ductility of the metal provides a safeguard against breakage in the event of collision or other accident—a factor of great importance in the carriage of certain chemicals.

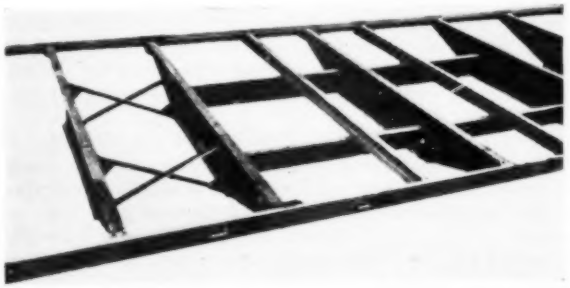
In constructing furniture pantechnicons, aluminium alloys enable an unladen weight of under 2½ tons to be achieved for a carrying capacity of well over 1,000 cubic feet. Special bodies have been developed in aluminium to suit other specialised requirements, for example, van bodies used for travelling exhibition purposes and the like, for "streamlining" is easily effected.

Van bodies having only partially closed sides, or simple platforms, have been built economically of aluminium alloy, thus giving striking testimony to the adaptability of this metal to all the different constructional uses involved.

Aluminium and Railways

We have some way to go yet in this country before we can match the extensive employment of aluminium which is to be found in the rolling stock of American and Continental railways. Yet applications of aluminium for such purposes are rapidly increasing in this country.

Generally speaking, it is not desirable to reduce to a large extent the total weight of a locomotive unit since to do so entails a corresponding reduction in rail adhesion. Forged and heat-treated aluminium alloys may, however, be used to advantage for connecting rods and similar parts where the lower modulus of elasticity of such alloys result in reduction of shock. The cab, brake cylinders, reservoir, running boards, fittings, etc., are other items which can, with advantage, be made from aluminium alloy. Considerable weight reduction may also be obtained by designing the bogies so that a large proportion of the steel is replaced by light alloys.



Courtesy of Messrs. Foden Ltd.

Underframe in aluminium alloy for a heavy Foden lorry

Window frames, doors, interior panelling, fittings and furniture can all be largely constructed of aluminium alloys. It is of interest to recall in this connection that the L.N.E.R. "Coronation" Expresses are fitted with aluminium screens, doors, combined roof lamps and ventilators, luggage compartments, lamp-box layouts, etc. Alloy NA30S8 was selected for the castings and NA2S and NA5IS for the extrusions.

Aluminium alloys have been used satisfactorily for panelling and body framework of Diesel railcars, a good example of which was built by the Northern Counties Committee of the L.M.S. railway. The panels, end-plates, roof and floor were of NA3S and NA4S alloy, while the framework sections, comprising pillars, cantrails and roofsticks were of heat-treated alloy. The G.W.R. Hardy Railcar was panelled in aluminium and the Birmingham Railway Carriage and Wagon Co. Ltd. have built a number of aluminium panelled railcars, among which can be mentioned those for the Entre Rios Railway Co.

In electric suburban and underground services the question of weight reduction is of great importance. Frequent stops and starts are a severe strain on the life of the wheels, brakeshoes, rails, etc., but, by reducing weight, this strain is minimised with a resultant saving in maintenance costs. Weight reduction also reduces the consumption of current, and increases acceleration and the speed at which services may be run.

In cases where the use of other metals may result in chemical action taking place between the goods and the container, as for example certain chemicals and foodstuffs, the containers of the wagons are being increasingly constructed of aluminium alloys.

Shipbuilding

No better instance could be cited of the increased use of aluminium in the shipbuilding industry than the decision

Courtesy of Aluminium Union Ltd.

Reception room of a newspaper office, fitted throughout with aluminium.

to construct two aluminium funnels in the new *Mauretania* of the Cunard-White Star Line. Alloys have recently been developed which compare favourably with the older alloys in cost, strength and availability in different forms, whilst, at the same time, showing corrosion-resistance approximating to that of the special Alclad series of alloys. A ship's superstructure is continually exposed to sea spray, and an alloy chosen for such work must necessarily possess suitable qualities, whilst other considerations like weight-saving and paint-adherence also enter into account. Thus, since funnels are now being constructed of aluminium alloys, in the near future we may well see the practice extended to davits, derricks, ventilators and a multitude of similar applications.

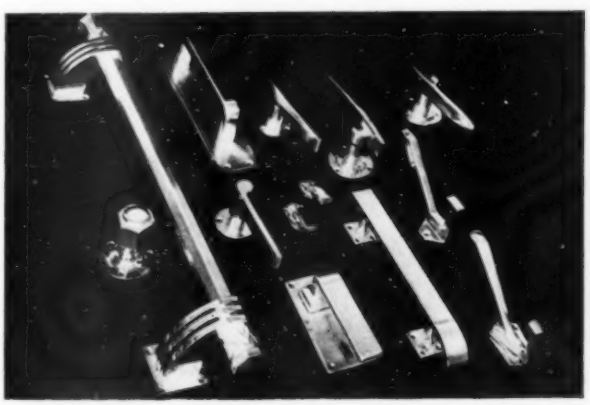
Considerable weight-saving can be effected in the engine room of a vessel. Aluminium and its alloys have already been used for such parts as gear casings, engine bedplates, crankcases, floor plates, air ejector covers, lubrication pumps, end brackets for electric motors, etc.; and above the water line for searchlight parts, portholes, grilles for lift enclosures, lockers and partitions. Aluminium alloy pistons are being supplied for Diesel engines in large quantities, some of these pistons each weighing 400 lb.

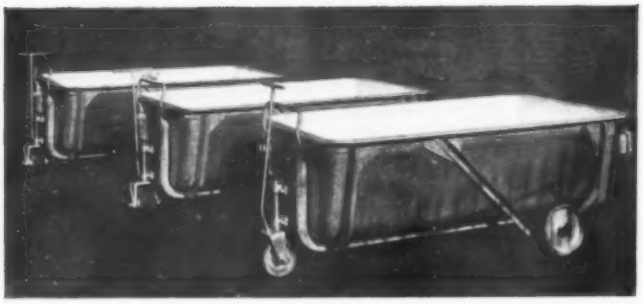
The risk of fire, which is no mean consideration where shipping is concerned, has been reduced to a material extent by substituting inflammable wooden partitions and bulkheads by bulkheads of light alloy construction. The most up-to-date method consists of enclosing a strong cement-impregnated canvas between two aluminium sheets. The posts and beams supporting these panels are also being constructed of aluminium alloy extruded sections.

In decorative and furniture effects, the navies of the world have led the way in using aluminium alloy chairs,

A few decorative aluminium alloy castings.

Courtesy of Aluminium Union Ltd.





Courtesy of Aluminium Plant and Vessel Co. Ltd.

Modern margarine wagons in aluminium.

tables, beds, cupboards, chests, etc., and now the ship-builders are following suit. Aluminium-silicon castings are used for electrical equipment, such as fuse boxes, etc., whilst large quantities of sheet, extrusions and tubing were incorporated for decorative purposes, furniture and door hardware, and cabin construction.

Architecture

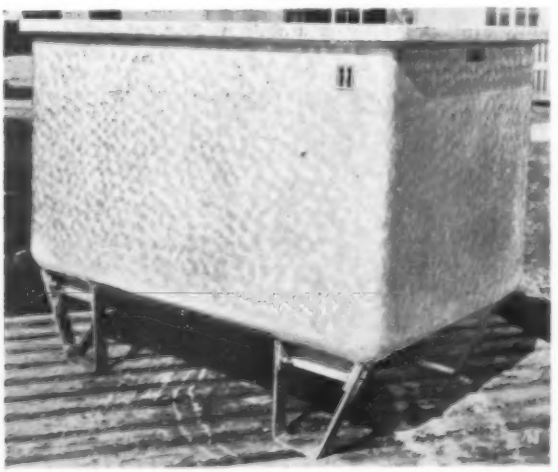
The rate at which the consumption of aluminium for architectural purposes has risen during recent years provides a clear indication that this metal possesses many advantages over other materials. It is available in large quantities and in all forms—castings, sheets, extruded sections and forgings—and is supplied in numerous alloys, each developed for a specific application.

It is a metal that is easily formed and machined, riveted and welded. Its low specific gravity means not only ease of handling and consequent speeding-up of production, but also less weight for the same size or alternatively larger sections for the same weight. Another important point in favour of aluminium for architectural purposes is the fact that this metal resists corrosion to a remarkable degree, and when anodised, painting is entirely eliminated. It is of interest, also, to bear in mind that this resistance to corrosion keeps adjacent surfaces free from disfiguring stains and streaks, a point worthy of consideration when light-coloured surfaces are predominant. The applications are many, and include the construction of doors, window frames, mullions and transomes, shop fronts, canopies, handrails, balustrades, grilles, door furniture, kicking plates, window breasts and all forms of decorative cast and formed work.

A wide range of suitable alloys is available in extruded form and it cannot be emphasised too strongly that such extrusions solve many of the architects' problems.

A recently-designed butter-wagon in aluminium.

Courtesy of Aluminium Union Ltd.



Standard sections can be used for the construction of balustrades, window frames, doors, etc., whilst other mouldings are specially produced for such purposes as stair nosings and guttering. Many sections are also produced which can be interlocked in order to reduce structural details and production costs, and the increasing use of these sections is a sure indication that this method is of great practical value.

A great deal of thought has been devoted to the question of maintaining the original bright polish of aluminium. Occasional cleaning will restore the brilliant finish of the unprotected metal, but if neglected a thin film of aluminium oxide is apt to form on the surface. A transparent film deposited electrically can, however, be obtained which enables the beautiful appearance of polished aluminium to be retained. Vast possibilities have also been opened up by the process of dyeing this anodic film before final sealing. A great variety of brilliant colours and also pastel shades is now at the disposal of architects and designers.

Anodic Oxidation

As an illustration of the applicable features of the inherent properties of the anodic film, namely, abrasion-resistance and the absorption of a suitable lubricant, it is only necessary to draw attention to the ever-increasing number of motor car manufacturers who are incorporating as standard in their engines the well-known LO : EX pistons treated by the " Alumilite " process.

Aluminium Paste Paint

Aluminium paste is aluminium pigment in its newest and most readily accepted form. In its manufacture granular particles of pure aluminium are processed in the presence of a volatile liquid to form " leaves " or flat flakes. The paste itself is brilliant in appearance, is readily miscible with any conventional paint vehicle and does not harden or skin in its container. Unlike the pigment in powder form, there is no dust or waste when incorporating with a vehicle to produce paint, and mixing by hand is rapid and clean.

When aluminium paste is mixed with an oil or varnish vehicle, the surface tension of the liquid causes the metal flakes to rise to the surface and to form an unbroken layer. When the paint is applied to any surface by brush, spray or dipping the same phenomenon occurs, the metal particles in the thin applied film forming upon its surface an overlapping layer. This pigment layer of pure aluminium, many flakes in depth, is quite opaque to light and consequently the vehicle itself is protected from the destructive influence of solar radiation.

The smooth surface of a film of aluminium-paste paint discourages the settlement of atmospheric dust particles. In consequence the surface remains clean and highly reflective whatever the exposure conditions. This high reflectivity characteristic may be used to advantage in the external painting of steel-sheet structures, for apart from the protection afforded to the metal sheets, a lower temperature in summer months and a more equable temperature during the winter are obtained.

Aluminium paint made from paste pigment may be applied to any surface, and as a primary paint for timber to be followed by subsequent conventional paint coatings it is unexcelled, checking as it does the movement of entrapped moisture, which is the chief cause of the failure of paint systems on timber.

Truly it can be said that we are in the *Aluminium Age*. New uses of the metal and its alloys are daily being discovered, and in just over 50 years an industry has been created which has revolutionised preconceived ideas. The progress of aluminium and its alloys during the next half century is likely to be even more striking and tribute should be paid to the metallurgists, chemists, physicists and engineers who have made possible such outstanding developments.

Progress and Trends in the Norwegian Aluminium Industry

By
JOHAN MÜRER
A/S Norsk Aluminium Company

Aluminium is being utilised in Norway to an ever increasing degree, in the same fields as are now common in the world's industries, but much pioneer and research work has to be done in the application of aluminium to the canning industry and in the manufacture of dairy appliances to which special reference is made in this article.

Opening an aluminium sardine container is as easy as winding a watch, a child can do it.

NORWAY, with its large available and easily-accessible quantities of hydro-electric power, developed an important aluminium industry at an early stage. The early application of the metal in the manufacture of kitchen utensils and in the foodstuff industry enabled the population of this country to become acquainted with the good properties of aluminium, with the result that to-day there are few homes where aluminium is not used. Large containers were also introduced to an appreciable extent in the early stages, in breweries, dairies, and in the chemical industry. Aluminium was also used at an early date for high-tension electric power transmission lines. In a number of these fields progress has been so great that the demand to-day can be said to have practically reached saturation point, when future consumption will depend mainly on the compensation for worn-out material and replenishment on a minor scale.

In the manufacture of aluminium kitchen utensils a development of considerable importance has recently been effected by the transition to cooking vessels possessing extra-heavy turned bottoms. Electric power companies have modified their price policy in order that householders can avail themselves of the advantages offered by electric cooking. As a result of the introduction of thick-bottomed cooking utensils—7 to 10 mm.—which permits the more economic exploitation of electric power, all parties are enthusiastic for the change and the transition is being effected at a rapid rate, which is appreciably increasing the consumption of metal in this field.

Following the development and introduction of the strong aluminium alloys, Norwegian industries have applied aluminium to an increasing degree in the same fields as are now recognised in industries in the world at large; in many respects, in fact, Norway has, to a great extent, led the way. In this article it is proposed to mention some of these developments in greater detail, and to indicate where progress has been promoted by pioneer work and research in this country.

The Canning Industry

A sphere which is believed to be peculiar to Norway, and in which A/S Norsk Aluminium Company has carried out extensive pioneer work, is that of the introduction of aluminium in the Norwegian canning industry. If it were possible to use aluminium packing for the entire fish-canning industry of Norway, the amount of aluminium absorbed annually would be about 6,000 tons. The introduction of this metal into the canning industry, therefore, raised a new and interesting problem for the aluminium industry. In view of the fact that the majority of the Norwegian conserves are exported, the light weight of the aluminium can is a factor of advantage, and since all tin, and to a great extent also all finished tinplates, are imported, the introduction of aluminium in the canning industry is a matter of national importance.

Mr. Kloumann, the general manager of A/S Norsk Aluminium Company, was the first to realise the possibilities in this direction. The experimental work on aluminium packing was initiated and patents taken out for an aluminium lid with opening grooves in a number of countries.

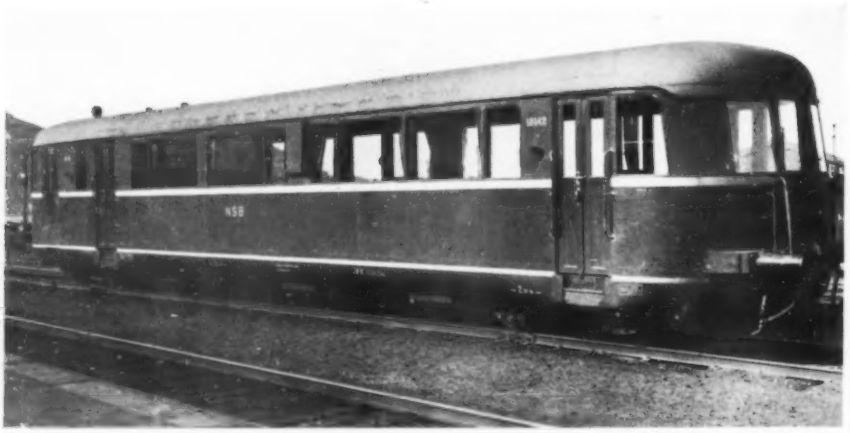
The first investigation in connection with aluminium packing was undertaken at the request of A/S Norsk Aluminium Company by the Research Laboratory of the Norwegian Canning Industry, and Dr. Gulbrand Lunde, Director of the Laboratory, published in 1932 the following summary of a paper on aluminium as a packing material for sardines and kippered herrings :

1. No inside blackening of the can.
2. No metallic taste or smell.
3. No contamination by injurious metals.
4. Easy opening.
5. Lighter weight (one $3\frac{3}{4}$ oz. can weighing only 25 grm).

The above-mentioned commodities, which are the two principal Norwegian canned-fish export products, have a marked tendency to corrode the inside of tinplate cans, and a metallic taste is thereby imparted to the contents. The earliest investigations proved that unprotected aluminium did not suffer from these disadvantages, and, as the cans are very easily opened, and their appearance is attractive, the new material proved competitive in the case of a large number of conserves for which it is suitable. When these important products are packed in tinplate cans, their quality is better preserved if the cans are lacquered, but the cost of lacquering decreases the difference in price between tinplate and aluminium cans.

Among the numerous scientific investigations carried out at the laboratory were feeding tests with rats through-

Specimens of aluminium fish conserve cans.



Light railcar trailer of the Norwegian State Railways. A/S Strömmens' Vaerksted.

out several generations, which proved that the animals, fed on sardines packed in aluminium, suffered no harm whatever. These tests showed that the negligible quantity of aluminium compounds introduced into the animals was not accumulated in the organism, but again excreted. It was also proved that aluminium was not injurious to the various vitamins contained in the canned products, and that the new metal was therefore quite innocuous in this respect. The first large lots were packed in 1929, and samples of the sardines still retain their excellent quality, and have no metallic taste or odour.

During the following three years the number of aluminium cans used increased to about three million. As a result of practical tests carried out during this period it was shown that fruit conserves, fish in tomato sauce, unsterilized conserves and unsweetened milk cannot yet be successfully packed in unprotected aluminium cans owing to formation of hydrogen. The contents of the cans were not affected, but it is, of course, necessary to avoid any swelling of the cans. The company, therefore, directed its attention to conserves which were found to be well adapted to packing in unprotected aluminium. In addition to sild, sardines and kippered herring a number of other products were found to lend themselves to preserving in aluminium, such as natural crabs, shrimps, fish balls, fresh herring and fresh fish in gelatine. Furthermore, various kinds of meat, particularly army supplies and provisions for tourists with high fat content proved to be capable of being packed in aluminium. For the packing of sild, sardines and kippered herring about 350 tons of aluminium were used in 1936, corresponding to about 15 million cans.

Investigations are constantly in progress with a view to improving the quality of the metal and to making the aluminium cans suitable, by means of new alloying additions and surface treatment, for the packing of other products which it has not hitherto been possible to conserve in aluminium.

These experiments are promising and bid fair to result in an increase in the use of aluminium. It is estimated that the 350 tons previously mentioned will be doubled in the course of the next few years.

The purity of the virgin metal hitherto intended for use in the canning industry has been 99·6%. The metal is carefully controlled during the melting and casting processes. It is supplied by A/S Norsk Aluminium Company's factories at Höyanger to the north of Bergen, is remelted and cast into slabs which are then rolled to coiled sheet at the company's rolling mills at Holmestrand. All processes are carried out according to the best contemporary practice in order to turn out a metal free from inclusions and with the highest possible resistance to corrosion. The coiled sheet is delivered to the stamping factories where the cans and lids are stamped out by automatic machines, each of which is capable of delivering more than 100,000 cans in an eight-hour day. The cans are then shipped to the various canning factories along the coast.

The appearance of the ordinary cans for packing sardines and kippered herrings has undergone a number of alterations in recent years. In the beginning trade marks and special texts were stamped on lids and cans. This has now been abandoned, and the cans are strengthened by means of corrugations in the bottoms, sides and lids, thus giving the cans an artistic and attractive appearance entirely different from those made from tinplate. The special appearance of the cans emphasises the good quality and durability of the contents and the facility with which the cans can be opened.

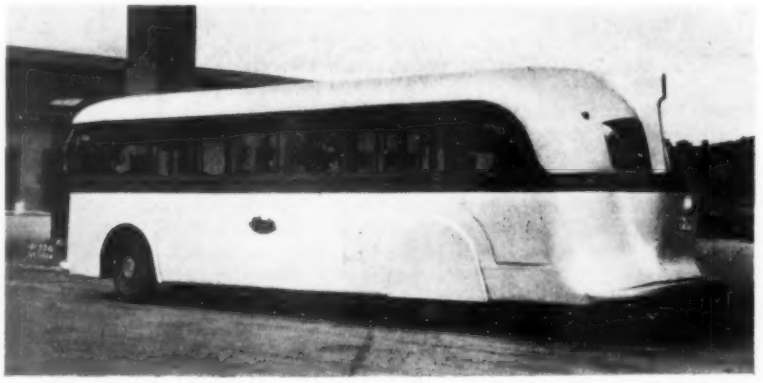
Sterilisation of aluminium cans must take place in super-pressure retorts. During sterilisation and cooling the pressure is higher than that corresponding to the sterilisation temperature, this being necessary in order to avoid straining the seams and to prevent the can assuming a swelled appearance. The physical properties of aluminium sheet are not the same as those of tinplate, and a modification of operating conditions during sterilisation is, therefore, necessary.

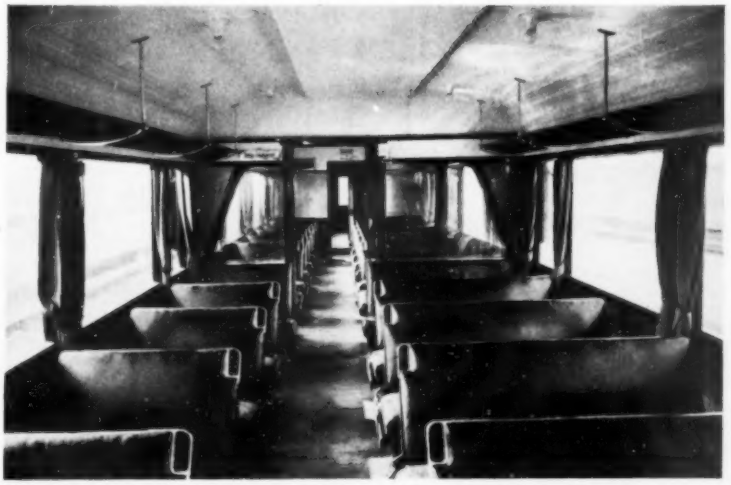
The practical results achieved during the seven to eight years, which have elapsed since the first lots of fish conserves were packed in aluminium in Norway, have shown aluminium to possess definite advantages in the case of a number of conserves, and that the first milestone in the advance of a new metal into the sphere of canning has been passed.

Aluminium in the Transport Industry

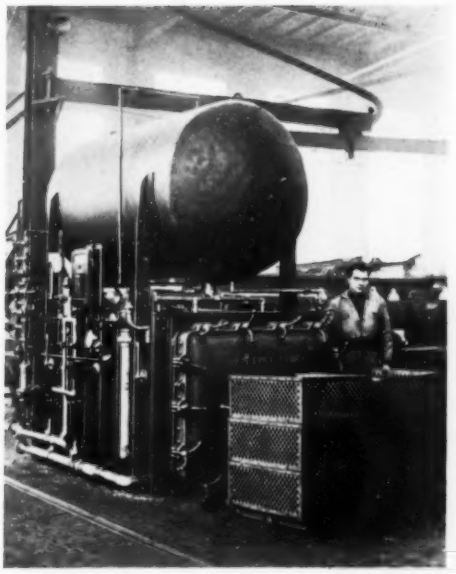
The topographical and climatic conditions in Norway present not only road engineers, but also rolling-stock engineers with a difficult task. The rolling-stock must not only possess such mechanical strength as will enable it to withstand the usual wear and tear under ordinary operating conditions, but it must be able to meet the heavy strain arising from a severe climate. Some of the railroads run through mountain passes 3,000 to 4,000 feet

Strömmens' type Oslo omnibus in aluminium.





Interior of a light railcar trailer on the Norwegian State Railways. A/S Strömmens' Vaerksted.



A/S Kvaerner Brug's super-pressure retort size RH-6, with a holding capacity of 11,400 —¼ Dingley cans when cans are stacked in can crates.

above sea level, and at these altitudes it is only during a few short months in the summer that precipitation takes another form than that of snow.

A topographical survey of Norway indicates very clearly the necessity for a light type of rolling-stock, and this necessity becomes imperative when, as in the case of Norway, all coal and oil must be imported. With an area of more than 125,000 square miles the population of Norway does not amount to more than 3,000,000 scattered over a distance of no less than 13° of latitude, and the average number of passengers carried by a railway train does not amount to more than 40.

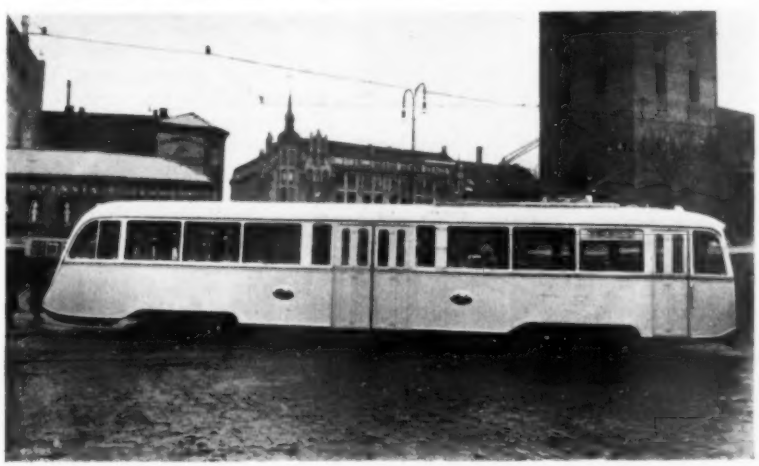
To surmount these difficulties the railway authorities introduced small gasolene-motor rail cars some years ago for experimental purposes, and to reduce their weight aluminium was used in their construction. In some of these cars, which were put into operation in 1932, about 2,600 lb. of aluminium was used, thus reducing the weight per car by 6,400 lb. These cars have proved to be so satisfactory that during the past two years a number of broad-gauge trailers and Diesel motor-cars have been ordered, with passenger accommodation, constructed almost entirely of aluminium and its strong alloys.

In the building of these trailers, each with seating accommodation for 69 passengers, about 5,700 lb. of aluminium was used, thus bringing the weight of the car down to 35,000 lb., and the weight per seated passenger to 510 lb. The body did not weigh more than 4,400 lb., while the total weight of the two steel bogies was 15,500 lb. The Diesel motor-cars with seating accommodation for 79 passengers weigh 53,000 lb. By coupling two Diesel motor-cars with one trailer a 600-h.p. train is secured, carrying 227 seated passengers, with a total dead weight not exceeding 141,000 lb.

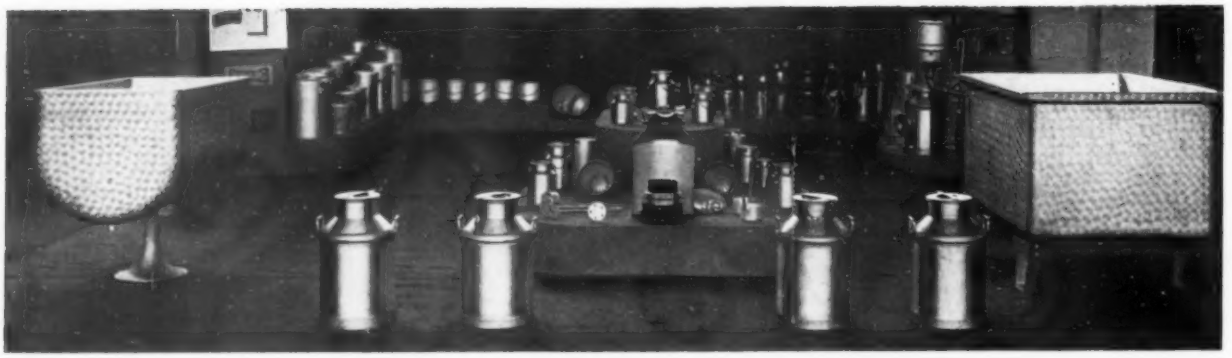
Some years before the railway authorities commenced to substitute aluminium for steel and non-ferrous alloys, aluminium had already been widely used in the motor-vehicle industries. During the past 10 years there is scarcely a motor-bus which has been built without having, at least, aluminium panels in the body.

The necessity for reducing weight has led to a more extensive use of aluminium by the Oslo Municipal Tramway Company in the construction of their motor-buses. It is quite clear that aluminium cannot be substituted for steel on the basis of first cost only, but if saving in power extended and lower maintenance charges due to decreased inertia and vibrational strain are taken into consideration the advantages derived from the use of aluminium quickly become apparent. As a result of seven years' experience of different types of motor-buses the Tramway Company has found that operating and maintenance costs were reduced from 82·65 öre per kilometre (1s. [illegible]d. per mile) for a steel bus weighing 16,500 lb. to 74·9 öre per kilometre (1s. 2½d. per mile) for an aluminium bus weighing 11,000 lb.

Strömmens' type Oslo tramcar constructed mainly in aluminium.



These buses are run in crowded city streets where the top speed between stops is, of necessity, limited to some extent, and where the ability to accelerate is a factor of great importance. As compared with a steel bus, the rate of acceleration of the lighter aluminium vehicle is about 45% higher, thus resulting in a higher speed, about 13% between stops. This in turn enables a service to be worked with 13 aluminium buses where 15 steel vehicles would otherwise be needed. The life of a bus is eight years, and by using the light aluminium buses the Tramway Company is able to effect a saving on the working budget of each vehicle of £4,000 during its lifetime. This means that the company save annually 1s. 10d. for each pound of dead-load reduction. It is also worth noting



An arrangement of aluminium milk and cream containers by A/S Norsk Aluminium Industry.

that the carrying capacity of these buses amounts to 90% of the dead load.

The company has followed up its success with these buses and has now at work electric tramcars built entirely of aluminium (except for the bogies). As compared with the most modern steel trams, which are run by a suburban tramway company, these aluminium trams, which have the same seating capacity weigh about 10 tons less. In view of the fact that the operating expenses per annum amounts to £25 per ton weight of car, the reduction effected by the use of these aluminium trams is equivalent to a substantial saving on the budget for working expenses.

The railway cars as well as the buses and tram-cars are of the self-supporting type with no separate underframe. Specially extruded shapes are extensively used, thus necessitating less material than would have been required in the case of more orthodox designs.

It may also be of interest to point out that the aluminium alloys have shown remarkable resistance to corrosion. After 5½ years of service, a part of one of the buses which had been subjected to heavy strain and only partly protected against corrosion, was taken out and thoroughly examined. No trace of corrosion could be found, and tests to which it was submitted proved the material to have better mechanical properties than those of new material.

The international dairy exhibition recently held in Berlin in conjunction with the Eleventh World Dairy Congress has given a strong impression of the increased interest shown in aluminium and its alloys in connection with dairying. This interest is concentrated particularly on transport pails made of aluminium, naturally enough on account of the lightness of the metal and its lasting properties in relation to the effects of lactic acid.

A number of characteristically agricultural countries have long used aluminium transport pails for the ordinary transportation of milk and cream, both from producer to dairy and from dairy to consumer, and an increase in the use of light-metal pails is an outstanding feature.

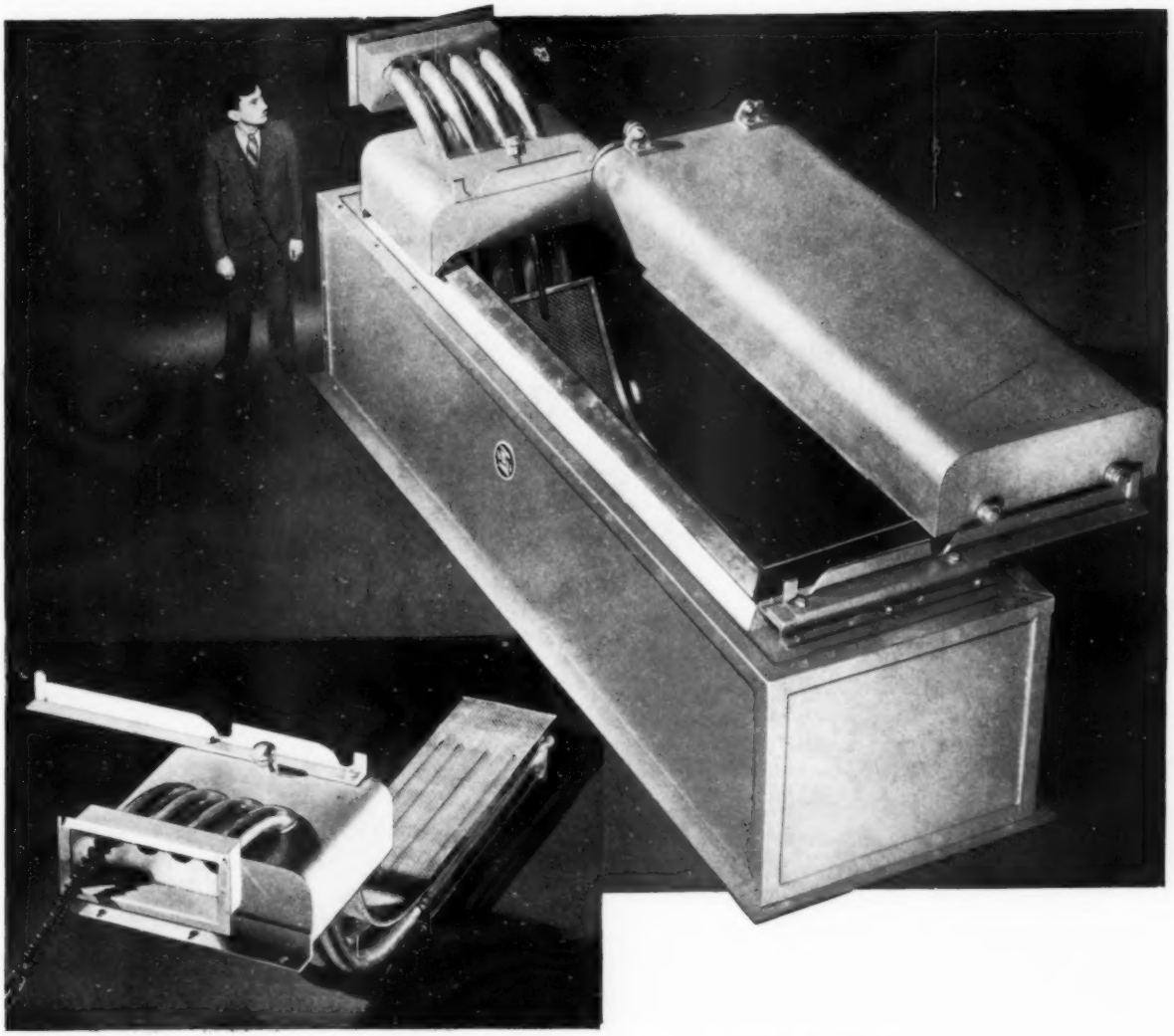
Norway is one of these countries which, on account of its mountainous nature, scattered population and farms and, in some cases, difficulties connected with communication, presents special problems in the organisation of its dairy industry. In this organisation of the higher situated and more distant small mountain farms which, from immemorial times have made their own butter and cheese, weekly transportations of salted cream have recently been commenced from such farms to the dairies, where the salted cream is successfully used for the production of butter. Even if the salt concentration employed does not exceed 0·75%, tinned pails will quickly be deprived of their layers of tin with a consequent unpalatable taste in the cream, in addition to the fact that the pails will soon be eaten through with rust. To a great extent, therefore, aluminium pails are used for this transportation, since, although the salted cream will, in the long run, also corrode the aluminium, this has no effect on the contents, which retain their fresh taste, while, apart from a negligible depreciation in weight which remains more theoretical than actual for many years, the pail remains unchanged.

Another sphere in dairying into which aluminium is gradually penetrating is that of milk cooling at the farms. Since official regulations were issued in Norway regarding the chilling of milk immediately after milking, and in addition to the fact that dairies have now commenced to pay for milk according to quality, the acquisition of milk-chilling apparatus has become a necessity. Apparatus of this character is made with advantage, as regards price, from aluminium, and it is recommended by the health authorities.

Water pressure is necessary for the cooler, which, with water double in quantity to that of the milk, cools the latter to only a few degrees higher than the temperature of the water. Moreover, the cooler contains a straining arrangement, and can be placed directly on to the transport pail. After having passed through the strainer, the milk does not come into contact with the air, and the cooling can, therefore, be done in the cow stalls or in the yard, where no special premises are available for the work.

Norsk Aluminium Company's factory at Höyanger, Sognefjord, Norway.

HEAT TREATMENT OF LIGHT ALLOYS



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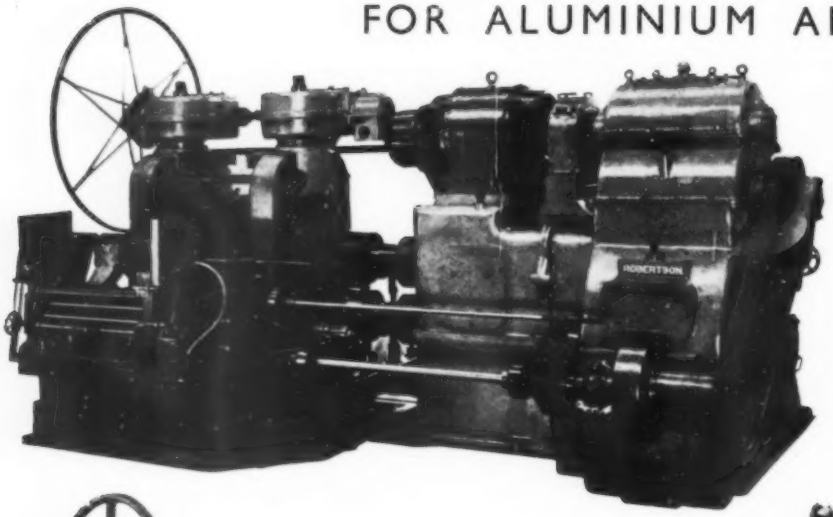
FOR ALUMINIUM AND ITS ALLOYS



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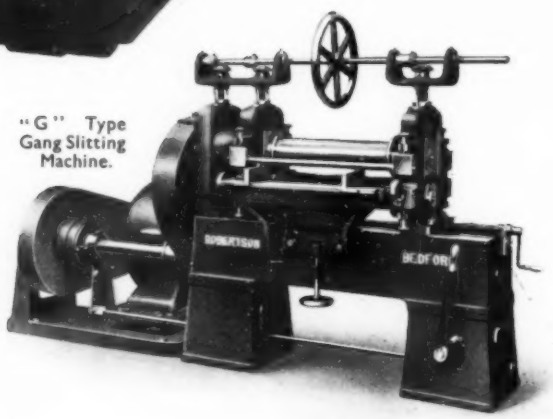
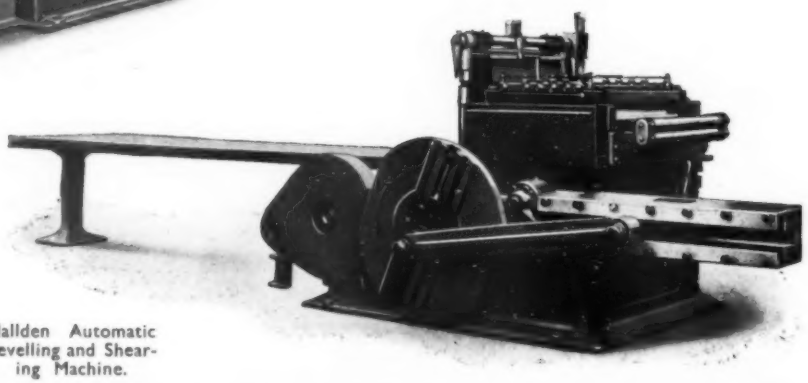


"G" Type Gang Slitting Machine.



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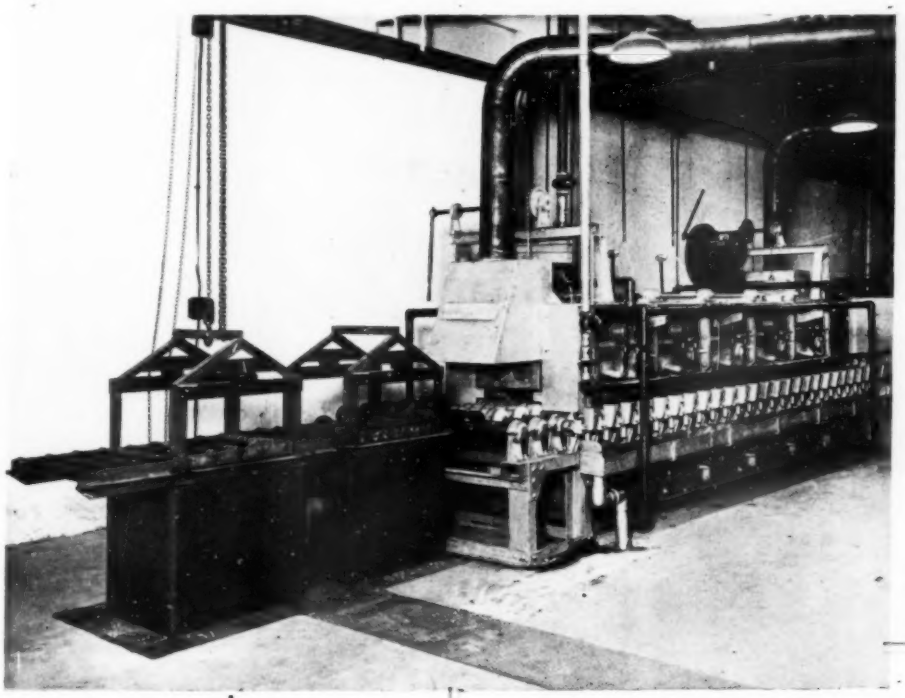

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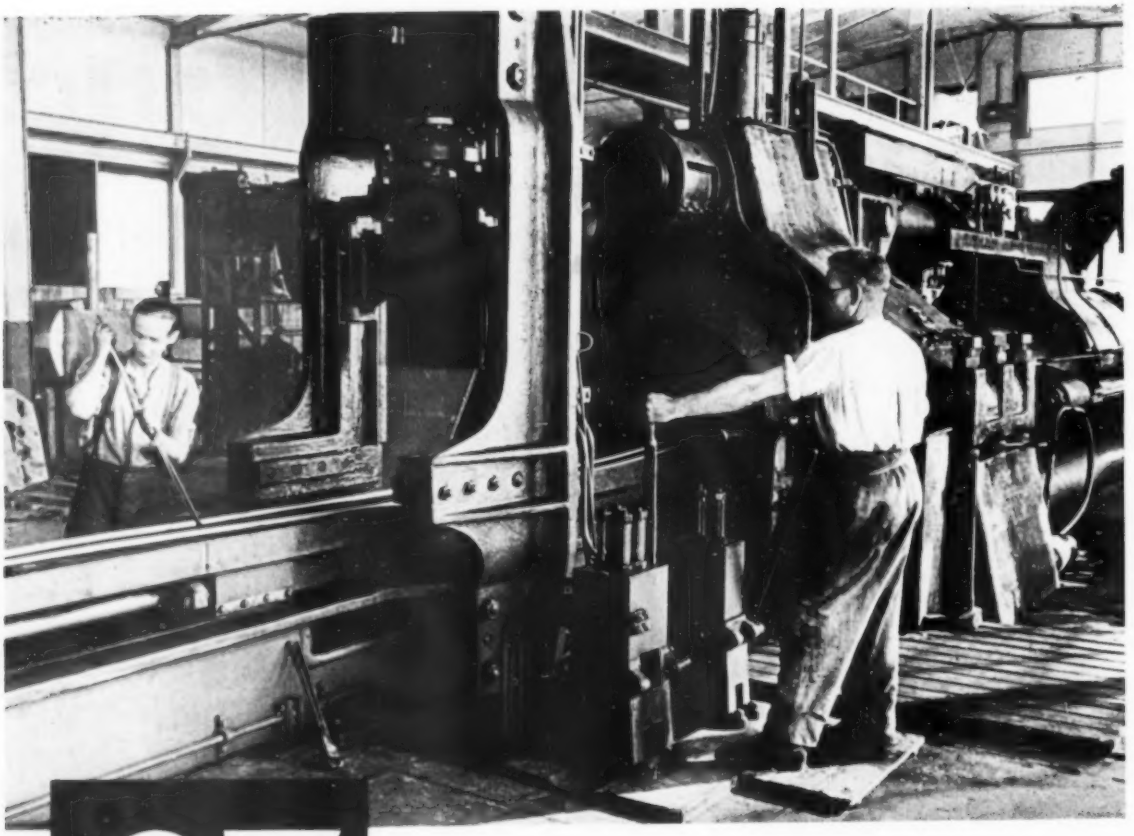

27

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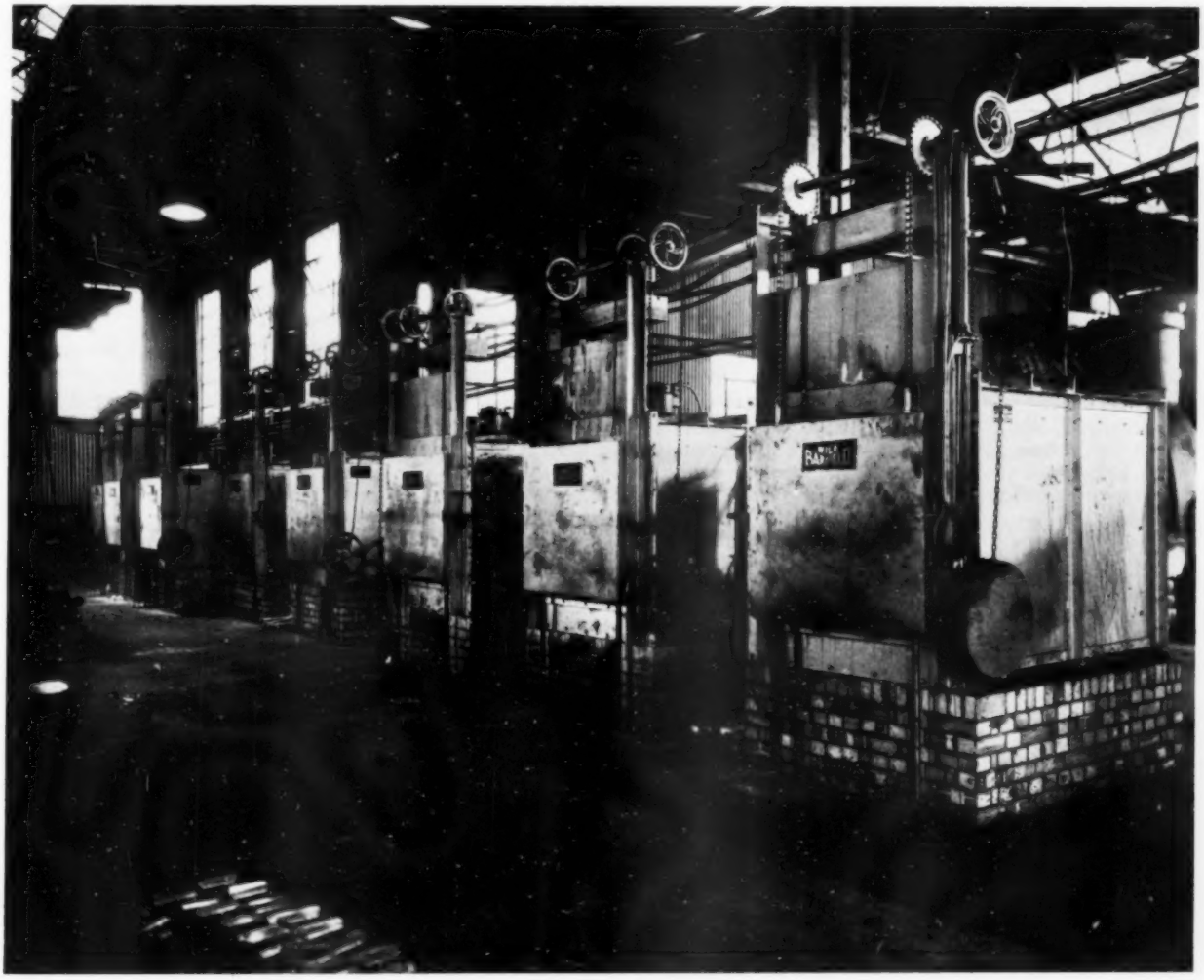

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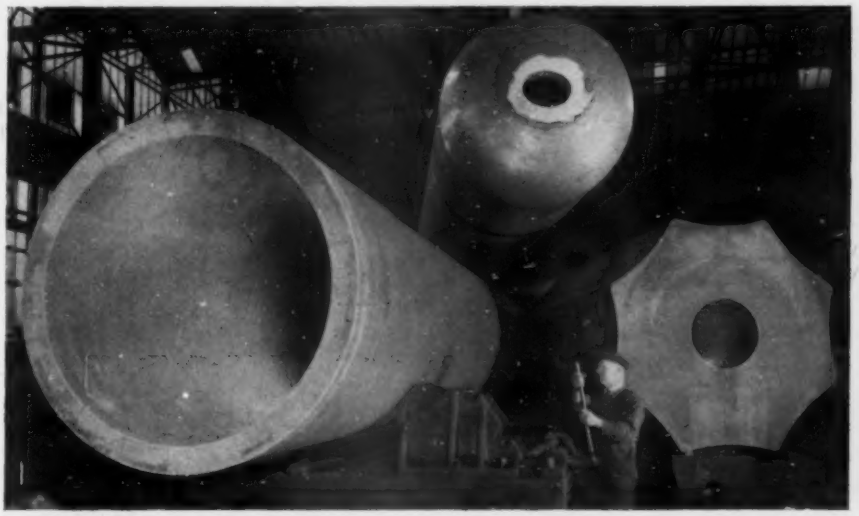
British Industries Fair

Each year, since the initial experiment, interest in the various sections of this Empire Fair has increased, and, in view of the number of exhibitors, the forthcoming Exhibition promises to be more comprehensive than in preceding years. In this review attention is directed to some of the exhibits which are of metallurgical interest.

RECOGNISED to be by far the largest display of entirely national manufactures held in any part of the world, this Fair is organised by the Department of Overseas Trade primarily to bring together potential buyers and manufacturers, with a view to promoting sales. It was tried as an experiment in 1915, and originally comprised five groups; but so great was the success of the venture that in each succeeding year there has been increasing interest displayed in the Exhibition, not only by manufacturers but by the general public. Since the initial experiment the space occupied by exhibits has multiplied almost ten times, and the various trades and industries represented now number about eighty. No single building is available to meet the requirements of exhibitors; for this reason it is divided into three main sections, which are housed at Olympia and Earls Court, London, and at Birmingham.

The British Industries Fair, which opens at Olympia on February 21 and remains open daily until March 4, is concerned only with British products. All goods displayed are manufactured within the British Empire, and only those who visit the different sections can fully appreciate the wide and comprehensive range of goods and manufactures which is embraced by this national effort. That its potentialities for increasing trade are great is generally recognised; apart from orders which are placed with exhibitors at the Fair, contacts are made which eventually result in business being done. We know of several instances where exhibiting firms have received inquiries regarding a particular product years after its exhibition at this Fair, which have led to substantial orders.



Three stages in the manufacture of seamless-steel boiler drums manufactured by Thos. Firth and John Brown Ltd., for Australia. Forged from ingots 19 ft. long, and weighing 150 tons, the drums when forged had an outside diameter of 70 in., and an overall length of 48 ft.

Apart from assembling before the largest number of potential buyers, both home and overseas, the greatest possible concentration of British manufactures, the Fair is a useful guide to progress, since it demonstrates advances in science and the arts, and provides the potential buyer with an opportunity for seeing the extent of progress in these directions and in making comparisons for present or future consideration. Apart from improvements in products, resulting from research, the display of manufactures in the various fields tends to effect improvements in the workmanship and finish of those exhibited, as each exhibitor endeavours to present his products in the most attractive form.

To what extent the present industrial prosperity in the United Kingdom is due to recent exhibitions of this character it would be very difficult to say, but there can be no doubt that, in many instances, the display of particular products and the personal contact with interested visitors has led, directly or indirectly, to the product being applied to a more general extent. At the present Fair many of the exhibitors, particularly those regarded as dealing with the heavy industries, will have difficulty in meeting requests for their manufactures. Quite a number are so congested with work in hand that promises of delivery for new orders will present a real problem; some even assert that their presence at this year's Fair is not so much to obtain new business, but to maintain prestige and to make contact with present and future customers.

Although it is generally admitted that Britain's prosperity is due largely to the greater demands of the home market, her share of the overseas trade is also increasing, and, since this latter trade is the most urgent need of the world to-day, the facilities afforded by the British Industries Fair, with the co-operation of the Department of Overseas Trade, should materially assist in widening the influence of export trade by the British Commonwealth. It should be borne in mind that world trade is based on business transactions carried through by individual firms, and each manufacturer should seek to encourage the flow of these individual transactions.

Each of these annual Fairs organised by the Department constitutes a new drive for world trade, and the exhibits show that the products of British industry in regard to scope, quality and workmanship are not exceeded by any other country, and their cost, having regard to service, will compare favourably with that of similar products manufactured elsewhere. In this article it is proposed to give a preliminary review of some of the more interesting exhibits of a metallurgical character.

METALLURGICAL DEVELOPMENTS

Iron and Steel

Since the Fair last year the iron and steel industry has made further progress in two main directions, viz., improvement and expansion of producing plants, and increased uniformity and reliability of product. A number of blast-furnaces have been modified and the charging facilities improved, with the object of enabling the furnaces to carry a heavier burden in an effort to meet the demands for pig

iron and steel. A full-scale blast-furnace field test has been carried out, and although a report of the investigation has been published, it has been considered desirable to extend the inquiry, and it is probable that other typical British blast-furnace conditions will be investigated, with a view to determining the characteristic physico-chemical feature of each, of comparing one with another, and, ultimately, of co-ordinating results as a whole with those of fundamental laboratory investigation, which is being carried out simultaneously. In this way it is hoped to provide a new scientific basis for British blast-furnace practice.

Another development with wide possibilities is the method of desulphurising pig iron. The method is being applied at the Corby Works of Messrs. Stewarts and Lloyds, where the local ore has a relatively high sulphur content, and it is required for basic Bessemer steel. In order to obtain a suitable slag, and permit smooth operation, the metal is being desulphurised outside the furnace. The furnaces are burdened and slagged without consideration of the sulphur content of the ores or the pig iron, but sulphur is reduced from 0·10 to 0·50% in the pig iron to about 0·06%, low enough for the Bessemer process, by treatment with a mixture of soda ash, crushed limestone and fluorspar. The chief desulphurising agent is the soda ash, the other constituents of the mixture assisting in the formation of a desirable slag. The amount of the mixture used averages about 2·4% of the iron treated.

Stainless steel heating coil by the Britannia Tube Co. Ltd.

Attention has also been directed to steel plants, with a view to effecting increased production at relatively lower operating costs. The design of many open-hearth furnaces has been modified and brought up to date, and the advantages of automatic control are being increasingly recognised. While operating near to capacity during the year, the industry has been preparing for an increased output to meet unsatisfied demands at home and abroad.

The efforts made to ensure increased uniformity and reliability of the materials manufactured are ceaseless. The increased demands of the engineer continually present new conditions which frequently call for new materials, modifications in existing materials, or modifications in the manufacturing operations. Nothing of a spectacular character has been discovered during the year, but research work has contributed towards a fuller knowledge in many fields of metallurgical activity. Applications of new or modified steels frequently begin in a very tentative manner, and are usually preceded by extensive investigations. Even when a new alloy is put into service, continuous study is necessary to develop a suitable manufacturing technique so that it can be forged, rolled or cast, and suitable heat-treatment operations developed, so that the steel may be properly worked and treated to have the desired properties.

Considerable research has been directed to the development of steels for use at elevated temperatures. Work carried out in the research laboratories of Metropolitan-Vickers has shown considerable promise. Attention has been given to the influence of prolonged thermal action of molybdenum-vanadium steel, and a heat-treatment has been determined which ensures that these steels, after treatment, will have suitable physical properties and stable creep resistance. Investigations are proceeding with a view to finding steels which have still further improved properties at elevated temperatures. The creep behaviour at atmospheric temperature of anti-vibration support steel has been investigated with the object of selecting the most suitable material.

With increasing development in the ferrous field, the range of steels available to the engineer to-day is rather alarming, especially when he is seeking the most suitable steel for a particular purpose. At the Birmingham section of the Fair, however, he has an opportunity of seeing the progress effected in the production of steel from those which have a tensile strength up to about 150 tons to the soft steels for deep drawing and stamping, the corrosion and heat-resisting steels having high and low coefficients of expansion, magnetic and non-magnetic steels, and steels possessing a tough core with a very hard case.

The heavy side of the manufactures of Thos. Firth and John Brown, Ltd., is represented by a large hollow-forged, seamless boiler drum, cut away to show the interior; die blocks; a range of castings as used in the mining, quarrying and associated industries; dredger buckets and spares; rolled steel bars; various examples of the application of Nitralloy steels noted for extreme hardness, and used for parts subject to hard wear, such as tyres, axles and springs.

The display unit for each group in the United Steel Companies exhibits has been planned to give, as far as practicable, a complete idea of the manufacture and application of the material shown. The development in the production of electric steels is of particular interest, as it is a result of the persistent demand of designers and engineers for cleaner and better steels. Intensive research into steelmaking methods has led to the standardisation of technique for production of the wide range of steels made. This range includes structural steels manufactured by Samuel Fox and Co., Ltd., which are subject to the "Diamet" code of inspection, ensuring materials as clean, homogeneous and regular in quality as is humanly possible. The various stages of "Diamet" inspection are shown by means of a chart and illustrations; an interesting feature is the checking for cleanness of each cast of steel by the Fox inclusion count method, which enables the degree of cleanness to be ascertained on a quantitative basis.

The modern automatic demands a steel of uniform composition; to ensure this feature "Phœnix" steel is produced under a rigid procedure of manufacture, and is followed at every stage of production. This steel was introduced about five years ago to supersede the old type free-cutting steels; it has been standardised as a rapid-machining steel, and is supplied in billet form by Steel, Peech and Tozer, and in bar form by United Strip and Bar Mills. Some examples of actual tests on this steel form part of the display, together with interesting examples showing core-ductility, case-hardening properties and uses with production speeds.

The Steel, Peech and Tozer branch of United Steel Companies is well equipped for the production of all types of heavy forgings. A cogging mill roll, 11 ft. 6 in. long by 3 ft. diameter, and weighing 10½ tons, is shown as an example of one type of forging in regular production. The display also includes hot-rolled and cold-rolled steel strip and wire in various qualities and finishes.

A comprehensive display of cold-rolled strip for all tempers, and a great variety of interesting pressings from special deep-stamping strip, are exhibited by J. B. and S. Lees, Ltd. The ductility of this steel strip is demonstrated by producing a difficult pressing on a single-action press in one operation. High-quality, hot-rolled steel strip is displayed by Arthur Lee and Sons, Ltd.

Stainless Steels

Developments in the manipulation of stainless steels are noticeable and they are increasing their fields of application. Prominent among the displays of stainless steels, Firth-Vickers Stainless Steels, Ltd., Stand No. D413/314, exhibit "Staybrite" and Firth stainless steels. The former is of the austenitic type, and embraces a wide range of grades for different purposes and various analyses. The products are represented by bars of various sizes; "Staybrite" steel sheets of different finishes, forgings, castings, cold-rolled strip and drop-stampings; whilst other forms of fabricated materials include wire, wire mesh, nuts, bolts, rivets and screws. The display also includes a range of articles for domestic purposes; the bright pleasing appearance of this steel and the fact that it will retain this finish indefinitely are much in its favour.

A series of comparatively new stainless steels, exhibited by Samuel Fox and Co., Ltd., of United Steel Companies, on Stands D512/613, continue to be marketed with increasing success. The process by which these steels are made ensures a remarkable freedom from non-metallic inclusions, with resultant ease of fabrication and resistance to corrosive attack. It would be impossible to display all the applications of this "Silver Fox" steel, but visitors will be interested in some of the applications in such trades as textile, food-production, brewing, dairy, etc. Further applications are shown on Stand D1132, at the Olympia section, which will have a strong appeal.

Steel Tubes

Among the many semi-finished products in this section that of tube is not the least important, in so many directions is tube used that it has become a speciality manufacture. Of particular interest in this field are the steel tubes of Stewarts and Lloyds, Ltd. The range shown on Stands D501/400 range from the smaller sizes to 54-in. bore; from their screwed and socketed tubes and fittings to large steel pipes for water, gas and sewage schemes, with a wide variety of joints suitable for the particular requirements of such mains.

Among the products fabricated from tubes, attention is drawn to various decorative gates and fencing work suitable for modern houses, demonstrating attractive styles, easily fabricated by welding. For such purposes steel tubes provide a material both strong and light, and their smooth rounded surface facilitates maintenance and reduces the chances of injury. Other varieties of tubes, particularly those of stainless steel, are displayed on several stands, including the Britannia Tube Co., Ltd., Accles and Pollock, Ltd., where many further applications of tubes make an interesting display.

Pig Irons

Ever-increasing severity of service conditions provide problems to the ironfounder and necessitate greater attention being given to the quality and character of his raw materials. In this field there are several exhibits that will interest the exacting foundryman. Noteworthy are the West Coast hæmatite irons, made from Cumberland ores by the Workington Iron and Steel branch of United Steel Companies, which are now produced by machine-casting. "U.C.O." refined irons have many special applications, and a range of these is displayed. Two working models of pig iron springs are shown by Stewarts and Lloyds which are interesting; they show the superior qualities of this firm's pig iron. Included in the display is an ingenious arrangement of samples of pig iron under a series of magnifying glasses, which enables their relative appearance and structure to be studied and compared.

Heat-resisting Products

There is an increasing market for products that will withstand relatively high temperatures and give long life in service, and attention is directed to the heat-treatment containers for case-hardening, cyanide, salt and lead hardening and annealing purposes exhibited by the Calorising Corporation of Great Britain, Ltd. On Stands D401/300 this Company show a few typical examples of their Calorised mild steel and Calmet nickel-chrome heat-resisting steels. These products are proving valuable for nitrate of soda baths for the heat-treatment of Duralumin parts, supports for oil-cracking stills, and for spiral conveyers, retorts, etc.

Other products of this type are displayed by Follsain Metals, Ltd., on Stand 713, which provide an efficient and economical means of withstanding severe conditions of high temperatures and oxidation. Two products in this

A sample of the soft-metal dies developed by Barronia Metals Ltd.

category are on view: Penetral HT aluminium impregnation process for rendering iron or steel resistant to oxidation at temperatures up to 1,000° C., and resistant also to sea-water corrosion; and EVHI alloy, which has a high resistance to creep and oxidation, and also to sulphurous fumes at temperatures up to 1,175° C. These products are applicable to boiler and heater plates and tubes, tube supports, furnace parts of all sorts, pyrometer sheaths, soot blowers, annealing boxes, carburising boxes, cyanide pots, boiler-gas deflector plates, dampers, etc.

Cutting Tools

Although few machine tools are on view at this Exhibition, there are several displays of cutting tools which are attractive. Among these attention is directed to that by Edgar Allen and Co., Ltd. This comprises "Stag Major Superweld" tools, which are butt-welded tools carrying an end of specially heat-treated super high-speed steel, firmly welded by electrical methods to a high-grade steel shank. A very comprehensive range of tools is also displayed by Thos. Firth and John Brown, Ltd., which includes files, "Speedicut" high-speed steel drills, reamers, cutters, butt-welded lathe tools, "Millenicut" files, hack-saw blades, "Insto" segmental saws, etc.

An entirely new range of standard tools, tipped with "Wimet" tool metal, is shown on Stand D408 by A. C. Wickman Ltd. These new standards are the result of co-operation with machine-tool makers in an effort to give designs which will cover all general machining operations. The new range opens up a new field of application on account of the metal's resistance to pitting and cratering from chip flow. Earlier grades of "Wimet," consisting of cemented tungsten-carbide alone, were very susceptible to chip action on account of the high affinity for steel, which is a characteristic of tungsten carbide. The addition of titanium carbide in certain proportions gives a great resistance to cratering, increasing the cutting efficiency and life of the tool. Of interest in this field are the Stag Allenite tungsten-carbide tipped tools, exhibited by Edgar Allen and Co., Ltd., specially designed for cutting cast-iron and non-ferrous materials. Those more especially interested in tungsten-carbide-tipped tools should not overlook those shown by Thos. Firth and John Brown, Ltd.

"Birlec" brazing and bright annealing furnace.

Steelworks Plant

There has been great progress in the development of various types of steelworks plant, and visitors interested in this field of activity should make a point of seeing the illuminated showcases of Newton, Chambers and Co., Ltd., which show several interesting structures by this Company. The actual exhibits include many products of interest to the steelworks manager. Further illuminated photographs of plant are shown by Messrs. Gibbon Bros. on Stand Ca511. This is a departure from this Company's usual practice of exhibiting a working furnace. The illustrations show several "Gibbon-Kogag" coke-oven plants, views of completed ovens, and others under construction.

A range of d.c. steelworks motors up to 200 h.p. has been introduced recently for driving approach and tilting tables, screw-down gear, manipulators, pushers, flying and up-cut shears, reels, pilers and other auxiliaries, and three machines, rated at 5, 10 and 25 h.p. when running at 1,025, 800 and 650 r.p.m., respectively, will be shown on the stand. Each size complies fully with the dimensions and ratings standardised by the American Association of Iron and Steel Electrical Engineers.

These motors are specially designed to reduce the inertia of the moving parts to a minimum to meet the requirements of quick starting, stopping and reversing. They are of particularly heavy construction to withstand the severest conditions of service, no cast iron being used. The shell is of cast steel, and is split slightly above the horizontal centre-line. For motors up to and including 75 h.p. the two halves of the shell are hinged in such a manner that the top half can be swung back, allowing the armature to be lifted vertically from the machine. Special consideration has been given to the selection of the insulation which has been chosen for its resistance to electrical, mechanical and heat stresses.

Malleable Iron Castings

The applications of malleable iron castings show no signs of abating as a result of competition from other products, evidence of this being shown by excellent displays of these castings for many trades and industries. The blackheart variety seems to predominate in the case of Hale and Hale Tipton, Ltd., and Leys Malleable Castings Co., Ltd. The former show examples of castings supplied to the British Admiralty, War Office, G.P.O., Crown Agents for the Colonies and foreign railways, and also include applications to the electrical, agricultural, dairy, domestic, textile, shipbuilding and motor-vehicle industries. Noteworthy in this exhibit are the products of a new foundry which deal with castings in "Halstal" for brake drums, brake shoes, bearings, etc., and general castings which require to have high-wearing qualities together with high-tensile strength; this material permits subsequent heat-treatment to a temperature of 600° C.

The control of the metal in the production of blackheart malleable castings is of vital importance, and this is a point stressed by Leys, of Derby, who specialise in the strict maintenance of a high standard of physical and machining qualities. It is of interest to note that a tensile strength of 24 tons per sq. in. is consistently maintained, with an elongation of 18%. Good machinability is another factor of importance. Here again the exhibits include examples for a great variety of purposes.

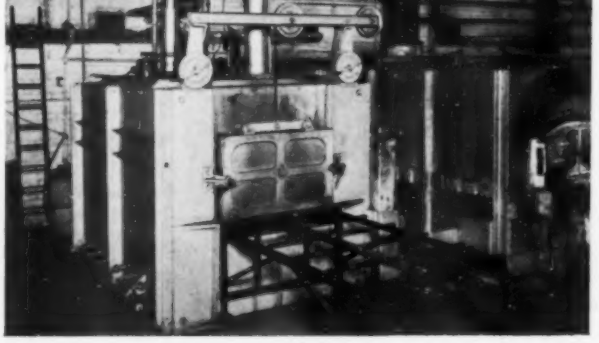
Non-ferrous Metals and Alloys

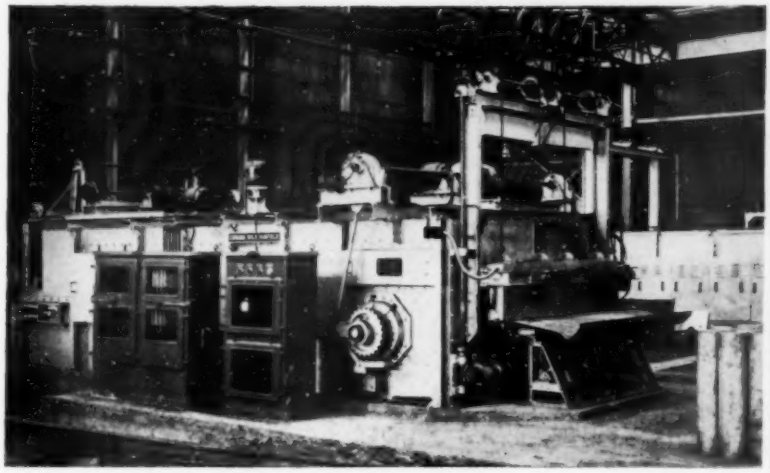
With the increasing severity of service conditions the provision of materials suitable for existing plant requirements is of vital importance, but no sooner is some degree of satisfaction attained than service conditions are made more severe, necessitating persistent work towards improvement. Considerable work has been devoted to the development of improved copper alloys, and the knowledge of the properties of the more common copper alloys has been enhanced. Considerable attention has been given to the improvement of copper-base alloys by nickel and aluminium additions, and, in general, various modified alloys containing additions of these elements are now preferred for severe service conditions.

Not the least striking of modern trends is the increasing applications of the light metals. Activity in this field has been directed to the improvement of existing alloys, and recent developments have resulted in the production of an aluminium alloy which, when solution treated and artificially aged, has an ultimate tensile strength of 33—38 tons per sq. in. With a specific gravity of 2·80, this is a valuable development when high strength/weight ratio is a vital factor. Improvements in magnesium alloys have led to the development of alloys which, in the heat-treated condition, have an ultimate tensile strength of 23 tons per sq. in. Here, again, the high strength/weight ratio is a valuable factor, since the specific gravity of the alloy is only 1·80. It is of interest to note that the United Kingdom is making great progress in the light metals field, and some good examples of this progress are on view at the Birmingham section of this Fair.

Since the last Fair, I.C.I. (Metals), Ltd., have made considerable headway with "Everdur"—copper with the strength of steel,—especially in the manufacture of storage tanks and heaters. Various forms of "Everdur" are shown on Stand D403/302, which demonstrate the high properties of this alloy and its many potential applications. Another interesting exhibit by this Company is an all-welded locomotive firebox, for the sideplates of which "Kuprodur" has been used. This is a new firebox material which overcomes plate wastage and stay leakage. "Kuniclad," or

Low-temperature heat-treatment furnace of the precision recirculating type fired by town gas and suitable for temperatures up to 700° C., by the Incandescent Heat Co. Ltd.





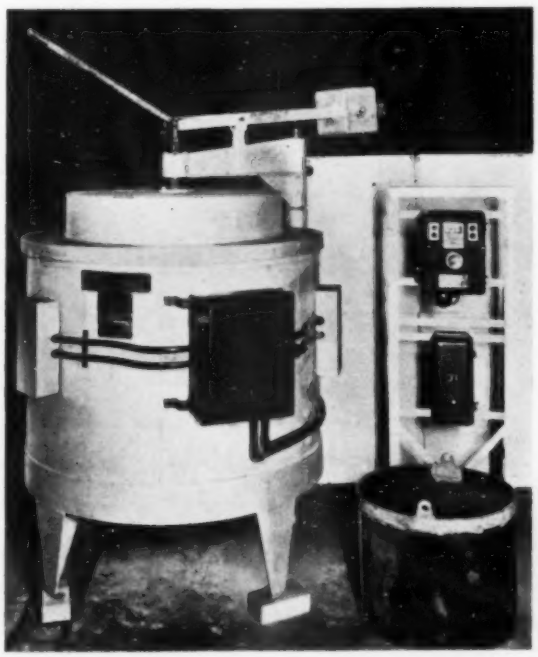
Fully automatic conveyer furnace for heat-treatment of aluminium-alloy billets prior to extrusion as tubes and sections by G.W.B. Electric Furnaces Ltd.

Bale-out furnace by Nu-way Heating Plants Ltd.

copper-clad drifted steel stay bolts, is also shown. The use of copper tubes for electrical conduit work have made considerable progress during the year, and demonstrations of the "Broduit" system will be given on this stand. Attention is also directed to cupro-nickel tubes, which are being supplied for the sister-ship of the *Queen Mary*. Other exhibits include high-conductivity strip for electrical work, wire of various kinds and gauges, and "Kynal" aluminium alloy in sheet and strip form for the aircraft and similar industries.

The preparation of various products for the many branches of the manufacturing electrical industry has been given particular attention during the year by Johnson, Matthey and Co., and the results of further research and production work are on view on Stand Cb211 in many interesting forms. Contact bi-metal has been developed, particularly as material for use in switchgear. Exhibits indicate the various forms in which this material is now employed. Of special interest is the display of precious metal catalysts. The catalystic properties of platinum, and other precious metals and alloys, are receiving constant and increasing attention, and this display indicates some of the types of catalyst now employed, and possible adaptations for other purposes. As in the previous year, demonstrations of silver solders and brazing alloys are given, including "Easyflo," "Silfos," and "Plumbsol."

Electrically-heated vertical type low-temperature annealing furnace by Metalectric Furnaces Ltd.



The investigation of such vital items as the mechanical and physical properties of metals, and their behaviour at high temperatures, is generally the work of specialists, and it is noteworthy that Barronia Metals, Ltd., have, for many years, placed the services of their research staff at the disposal of the engineering industry; some examples of metallurgical problems which they have solved are shown on their stand. The display includes a corrosion-resisting alloy, Barronia metal, the "Berdo" range of high-duty nickel-lead alloys, and the lead and zinc soft-metal dies, recently developed for forming aircraft fairings and similar panels.

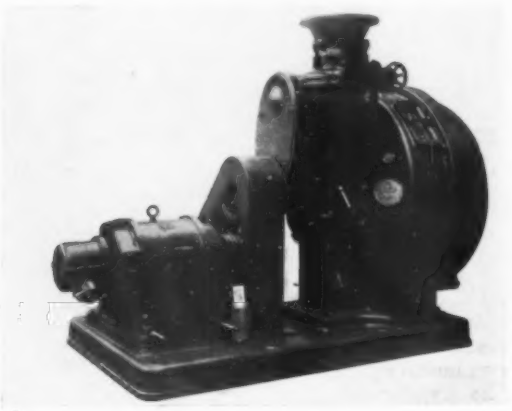
Rolled and extruded products are in great variety, and it is only possible to mention some here. The consistent development of cluster and four-high mills has enabled Emery Bros., Ltd., to concentrate on wider capacities, power economy, and greater uniformity and controllability in the manufacture of copper, brass and bronze strip. In addition to three cluster and one four-high mill, annealing is carried out solely by electric furnaces; the qualities of the cast billets and of the subsequently rolled material, therefore, are of a very high order.

Barker and Allen, Ltd., show a large range of products in nickel silver, brass and copper, bright rolled and soft. Attention is directed particularly to bright rolled, tempered nickel silver for the telephone industry, and also bright-finished brass for gas meters. Earl, Bourne and Co. also have a very comprehensive display of brass, copper, and aluminium-alloy strip, sheet, tubes, angles, channels, and other sections; while Enfield Rolling Mills, Ltd. show non-ferrous metals rolled, drawn and extruded in the form of sheets, coils, circles and sections produced from copper, brass and zinc. An interesting exhibit by the latter Company is a sloping roof showing a practical application of zinc both as a roof covering and for guttering.

Applications of tubes and extruded sections in many materials is admirably shown by Reynolds Tube Co., Ltd., on Stand D. 623/522 in the construction of the stand. The framework and the windows are made up of light-alloy extruded sections. A good example of hollow extruded work is provided by the large pillars at the front entrance. Light-alloy sheet has also been used for the panelling. The exhibits include steel tubes in all grades and types, circular and non-circular, together with many

examples of manipulated tubes and built-up welded structures which are made to very close limits for interchangeability.

On the light-alloy side, tubes, rods, bars, extruded sections, sheet and strip, in Hiduminium RR alloys, are shown, as well as manipulations, both tubular and solid, in many shapes and sizes. The wide range of extruded sections give a good indication of the progress in their production and in their utility to industry. A recent development is the production of tubes in Barronia metal for high-pressure hydraulic work. Tubes of small diameter and gauge have withstood pressures up to 7,000 lb. per sq. in., and they are being used on many hydraulic brake systems where absolute reliability is essential.



Atritor coal pulveriser

Melting and Heat-treatment Furnaces

Increasing accuracy demanded by modern industrial technique is responsible for a continual lowering of the permissible degree of tolerance in industrial operations, and since heat-treatment has such a great influence on the finished product, the question of suitable furnaces is one which requires careful consideration. Visitors at the Birmingham section of the Fair will see many examples of the furnace-designer's interpretation of modern requirements, in which electricity and many different types of fuel are used.

Of considerable interest is a continuous-belt conveyer-type furnace by Birmingham Electric Furnaces, Ltd. for brazing and bright annealing. This furnace operates with an atmosphere supplied from an I.C.I. patented recirculating type ammonia burner. This is the first time a furnace, designed for and operating with this type of ammonia burner, has been exhibited, and this firm is the first to apply this type of burner to a continuous conveyer-type furnace on a commercial scale.

This furnace, which is shown on Stand Cb313/214, has a rating of 25 kw., with a conveyer belt 12 in. wide. It is capable of operating at temperatures up to, or slightly exceeding, 1,100° C., and can be used for the bright copper brazing of steel and other articles, or for bright annealing, bright normalising, etc., of both ferrous and non-ferrous materials and parts. This furnace is in actual operation on the stand both for bright annealing and for brazing, and interested firms are encouraged to take samples of their products for treatment in this equipment as a demonstration of its capabilities.

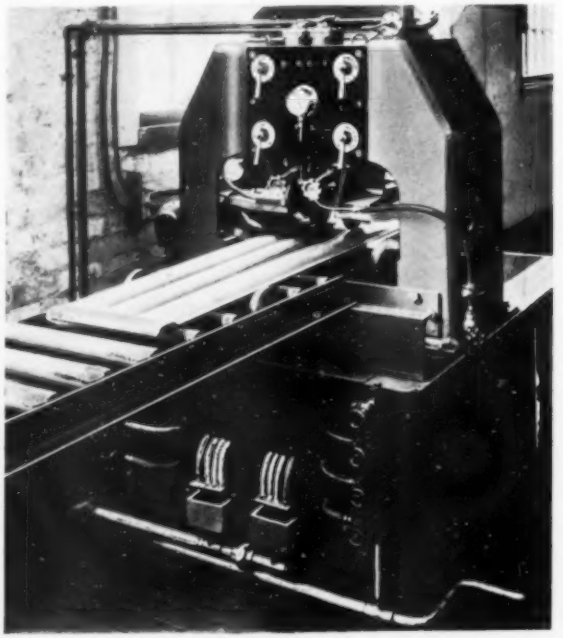
The whole range of Birlec heat-treatment and melting furnaces will be displayed in the form of photographs, while, additionally, the Birlec-Detroit rocking, indirect arc-melting furnace and the Birlec-Lectromelt direct arc-melting furnace are exhibited in model form, the full-size equipment being, in many cases, too large to show at the Fair.

A wide range of different types of electric furnaces, both industrial and laboratory, are also shown by Wild-Barfield Electric Furnaces, Ltd. Many of the types, because of their size, will be illustrated by photographs, but a number of actual furnaces are exhibited. These include muffle furnaces, which are very economical to run and meet many requirements. Two high-speed steel-hardening furnaces are shown. One is intended for hardening small tools. The high-temperature chamber is mounted above the preheater on one stand with the necessary electrical equipment below. The larger equipment consists of two separate furnaces mounted side by side, each being self-contained, except that the automatic control panels are arranged for wall mounting. The design of both these furnaces has been considerably improved, and now all the door-operating gear, pipework for the " Counterscale-Curtain " atmosphere control are concealed inside the case. Both these furnaces are available with manual, electric or pneumatic door operation. A " Tubular Hairpin " furnace is also on view, in which the tubular elements enable the furnace to be used up to 1,150° C.

The Wild-Barfield air circulation furnace is represented by two models, one intended for tool-room work, but which may be used for tempering where small output is required, or for experimental purposes. The other model is the smallest production size, and is fitted with a Charge Progress Recorder, which combines an automatic temperature controller with a two-point recorder—one a record of the furnace, and the other the charge temperature.

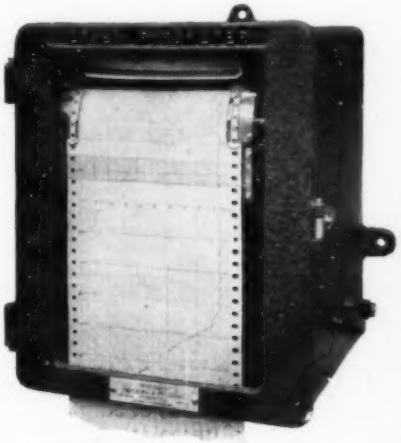
Those who are interested in the larger heat-treatment furnaces will find it useful to examine photographs of some of the typical installations by G.W.B. Electric Furnaces Ltd. Of particular interest are two large furnaces for dealing with aluminium, one a fully automatic conveyer furnace for heat-treating billets prior to extrusion as tubes and sections, and the other a large roller hearth furnace for treating aluminium billets prior to forging into aero-engine components, such as propellers. Other installations include two slat-conveyer-type furnaces for annealing cast-iron motor-car pistons ; a wire patenting furnace ; two pusher-type furnaces for annealing brass components ; a rotary-drum furnace for annealing small brass parts ; an inclined hearth furnace, also for aluminium billets ; a batch of four box-type furnaces for annealing brass and bronze strip in coils ; and a bell-type furnace for bright annealing coils of wire at temperatures up to 1,100° C.

A 120 kVA double seam welding machine by Metropolitan-Vickers at work on transformer radiator sections



Several interesting melting and heat-treatment furnaces are exhibited by Metalectric Furnaces Ltd.; these include a crucible furnace for melting aluminium and its alloys, which is claimed to be the latest type with lip-tilting, motor operation. The windings are of unique design and of patented construction which allows the removal of the elements whilst the furnace is under temperature. The display also includes a model of this firm's "Tagliaferri" arc furnace for melting iron, steel or ferro-alloys.

A number of heat-treatment furnaces are exhibited by Metalectric, one being a portable type for general heat-treatment up to 1,000° C., another being a recirculated atmosphere furnace for heat-treatment operations up to a temperature of 600° C., which incorporates a patent recirculated atmosphere fan, while a small laboratory-type furnace is also shown.



Controlling recorder by Ether Ltd.

Indicating controller by Ether Ltd.

25 kVA electric continuous spot welding machine by Holden and Hunt

Gas Furnaces

All interested in industrial furnaces should see the exhibits of the British Gas Federation in the Gas Section, for here are gathered together the individual exhibits of over 70 of the largest manufacturers of gas appliances, etc., throughout the country. In recent years so much progress has been made in the development and design of suitable equipment that the sales of gas for industrial purposes have shown astonishing expansion. In this display the Federation illustrate a number of the processes in which gas is used in some 4,000 different trades.

Considerable attention is given to factory heating, but of particular interest to readers are working demonstrations which include die casting in aluminium bronze; hot brass pressing; and high-speed steel hardening. The die-casting demonstration is staged by a large firm of die casters whose factory is equipped throughout with town-gas-fired furnaces.

Included in this exhibit is a laboratory equipment fitted with instantaneous water heaters, sand baths, hot plates, tube furnaces, muffle furnaces and Bunsen burners. Other exhibits include recirculated atmosphere enamelling oven, recirculated atmosphere-tempering furnaces, salt-bath furnace, and automatic-control appliances of all kinds.

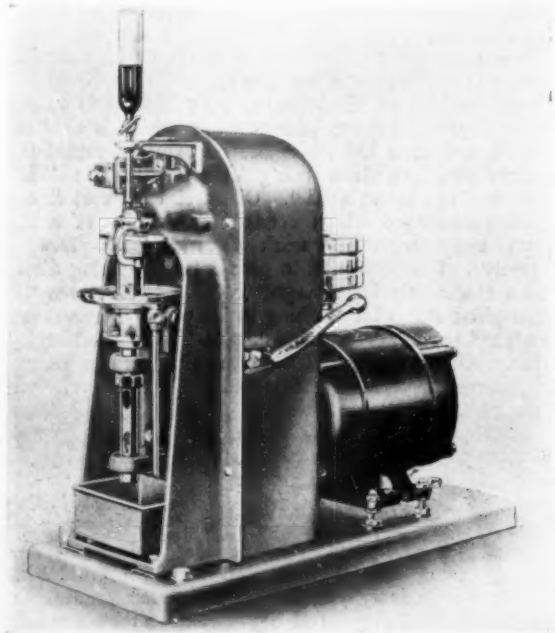
The Incandescent Heat Co., Ltd. exhibit a deep recuperative furnace fired by town gas, suitable for all heating and heat-treatment opertions up to 1,200° C. Another interesting furnace fired by town gas, which is shown by this firm is a low-temperature heat-treatment furnace suitable for temperatures up to 700° C. Furnaces of this type are being used to an increasing extent in the light metal industry.

Other exhibits include an oil-fired general-purpose heat-treatment furnace for temperatures up to 1,000° C., together with a number of small furnaces for various processes. Burner equipment and small muffle furnaces, soldering stoves, gas and air mixing appliances, brazing burners, etc., are shown on the same stand by the Selas Gas and Engineering Co. Ltd.

An interesting exhibit is that of Cassell Cyanide Co., on Stand D. 206, which shows a working furnace using "Rapideep," and visitors are invited to take samples of work for case-hardening treatment. Case depths obtained by this means are deeper than by a cyanide bath, and have the advantage of being glass-hard for over half their depth, as compared with a third with cyanide. Processes developed by this company cover heat-treatment and case-hardening in salt baths, including the hardening of high-speed steel. Salts are available for use at temperatures from 150° C. to 1,400° C., and furnaces can be supplied for these temperatures heated by gas, oil, or electricity.

The firm establishment in popularity of bright annealing in the metal industry lends particular interest to the complete installation of G.E.C. bright-annealing plant, which will be in operation throughout the period of the Fair. The installation comprises a 55-kw. electric furnace

Avery-Brownsdon wear and lubricant tester



together with the necessary automatic temperature control gear, Cambridge charge temperature indicator, main switchgear, and equipment for providing a suitable artificial atmosphere. Three pots, each with an effective loading space 48 in. deep by 24 in. diameter, will be used in conjunction with the furnace, which will be sunk flush with the ground to reproduce usual working conditions, and the loaded pots will be handled by a Witton-Kramer overhead hoist with electric lift and hand traverse.

Atritor Unit Coal Pulveriser

In previous years Alfred Herbert Ltd. have demonstrated the ring main distribution system, whereby one Atritor coal pulveriser is arranged to fire a number of furnaces such as those used in the drop forging industry. Each furnace has independent control, and as many as 14 furnaces in close proximity can be fired in this way. On the present occasion an alternative method is exhibited in which the Atritor fires two furnaces on the independent-feeder system. This system is intended for firing furnaces which are widely scattered and are working spasmodically so that the variation in the total fuel requirements is large. Only one pulveriser is used to fire all the furnaces. Coal is fed into the hopper of the Atritor, the amount passing into the machine being controlled by a handwheel.

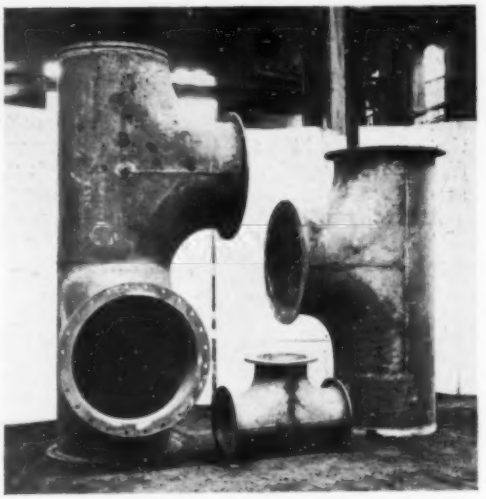
The application of this device to the firing of metallurgical furnaces has been particularly successful and includes smelting and refining furnaces for copper or furnaces for malleable iron, reheating furnaces for iron piling, and for heating steel ingots, blooms and billets, forge furnaces of all kinds, low-temperature furnaces for annealing steel or malleable-iron castings, cold-rolled strip or heating hot pressings.

A rather novel way of heating furnaces is exhibited by Mirrlees, Bickerton and Day Ltd. This consists of an automatic stoker which is self-contained and suitable for burning a cheap grade of fuel which is supplied by the underfed method ensuring good combustion and high thermal efficiency. It is understood that many of their installations have been applied to various types of furnaces, including those for Sheradizing, forge work, annealing and heat-treatment generally.

Several oil burners are exhibited and attention is directed to those by Nu-way Heating Plants Ltd., on Stand D. 106. The Rotavac oil burner is displayed in operation firing a special chamber. This burner, due to its atomising properties, handles 200-seconds oil cold, providing this is sufficiently fluid to flow to the burner. Its special features include a well-diffused gaseous flame, the length of which can be varied at will, and a wide range of fuel consumption for the burner. Another interesting exhibit is a Rotavac-fired heat-treatment furnace for small parts. This furnace is in operation at an approximate cost of 1½d. per hour, and the equivalent of 3d. per therm. A Rotavac aluminium bale-out furnace is also on view, the main features of which are the gaseous flame with consequent prolonged crucible life, and absence of carbon formation claimed.

B.O.C. 55-in. universal oxygen cutting machine in use for making 6-in. thick driving dogs from steel forgings

Large welded pipe connections by Ruston and Hornsby

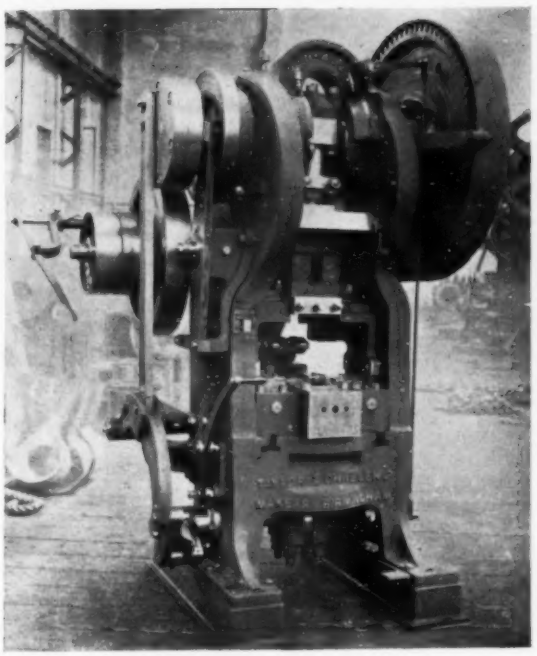


Laboratory Equipment

In recent years several new machines have been developed for testing purposes; one of these is the Avery-Brownsdon wear and lubricant tester, which is exhibited by W. and T. Avery Ltd., on Stand D. 515/413. This machine is designed to show the relative resistance to wear of various metals and the relative efficiencies of lubricants in preventing wear. In each case a flat specimen is held by a known force against a hardened revolving wheel the periphery of which is supplied with lubricant. After a certain time-interval the specimen is removed and the length of the elliptical impression is measured. Amongst other testing equipment shown are two universal-type machines of 10 tons and 50 tons capacity, an electrically-operated spring scragger, an impact tester, a direct-reading hardness tester for rapid tests, and a fatigue-testing machine.

The majority of the laboratory equipment is exhibited at the Olympia section prominent in which is that of W. Watson and Sons Ltd., who show a range of metallurgical microscopes, attention being directed to the "Metallograph," the latest model. Of special interest is a new bench microscope which consists essentially of a microscope body with rackwork focusing, eye-piece and objective. It is designed to give a long working distance, and a reasonably high magnification. It is shown with a plain pillar stand for working at bench level, but it can be furnished mounted on a bracket to fit the headstock of a lathe. Other exhibits include a new design of profile projector, a new and simple polishing machine, and the "Sayce-Watson" camera.

Another well-known instrument, the Vickers' projection microscope, is on view at the Olympia section by Cooke, Troughton and Simms, Ltd. Both models I and II are shown as well as a metallurgical bench microscope. The Vickers' projection microscope is arranged for the examination of both opaque and transparent specimens under a wide range of magnification and variety of illumination, and is particularly suited for commercial and research laboratories. On model II the projection distance is fixed



100-ton crank press by Taylor and Challen Ltd.

whereas model I enables an infinite variation of magnification. In the latter instrument the projection distance is adjustable between 16 in. and 36 in., and it is equipped with a comparison screen and exposure indicating device.

Temperature Control

Modern conditions demand such careful control in heat-treatment operations and the tolerance limits are, in many cases, so small that temperature indicator and recorders are now practically essential. Many exhibits of this type of equipment are shown in connection with the heat-treatment furnace displays, especially in the gas section, but particulars of all these exhibits are not available at the time of going to press. A number of instruments which have been developed to meet exceptional conditions, however, are displayed by Ether Ltd., on Stand Cb. 716. The stringent limits have called for more extensive use of automatic control and recording of furnace and salt-bath temperatures. The Ether Controlling Recorder has been designed to control the temperature of gas- and oil-fired furnaces in conjunction with motor- and solenoid-operated valves. The motor-driven units also operate dampers and air supplies. The controlling recorders provide, in addition, an output and progress record of the furnace operation.

Indicating controllers are also on view ; these instruments are used for controlling temperatures when no permanent records are required; they also control electric-furnace temperatures by operating the contactor coil without interposed relays. This control system is distinguished by its extreme simplicity and high accuracy. Included in this exhibit are thermo-electric and resistance pyrometers for a wide range of industrial purposes.

Forging Machines and Presses

One of the most interesting exhibits is that of Greenwood and Batley Ltd., on Stand D. 313/214 ; here a complete screw-making plant is under full production similar to normal working conditions, and visitors are able to see bolts and screws completely manufactured from the coil of rod to the finished article by the cold upsetting process. Two types of cold upsetters are exhibited, the open die and the solid die; in addition other machines operating include the bolt-head trimming machine for trimming cheese-head bolts to hexagon, the thread-rolling machine for rolling the screw thread on the shanks of the bolts, and the automatic nut-tapping machine which puts the threads on the nuts. A full range of samples of work produced by cold upsetting is included, forming an exhibit which will prove very attractive.

A number of presses will also be in operation in order that some idea of their capacity can be given to the interested visitor : some of these are exhibited by Taylor and Challen Ltd. on Stand D. 409. The largest is a 100-ton capacity crank press, fitted with a patented attachment for the production of articles of hot brass-work having four cores at right angles, such as taps, etc. The press is of double-sided design with an 8-in. stroke, which operates at 60 strokes per minute. It is fitted with an improved clutch, and is driven through single gearing from a back-shaft. The two dies are split vertically; one is fixed to the vice back, while the other is carried on a toggle slide, so that it may be moved back for the extraction of the finished article. By a special arrangement the two dies are pinched tightly together at the moment of application of pressure, so that no flash is formed.

A small automatic coining press for the production of coins or medals up to $\frac{3}{4}$ in. is also on view, together with a 70-ton friction-screw press, a 40-ton geared open-front press and an automatic notching press for the production of small stator stampings.

Refractories

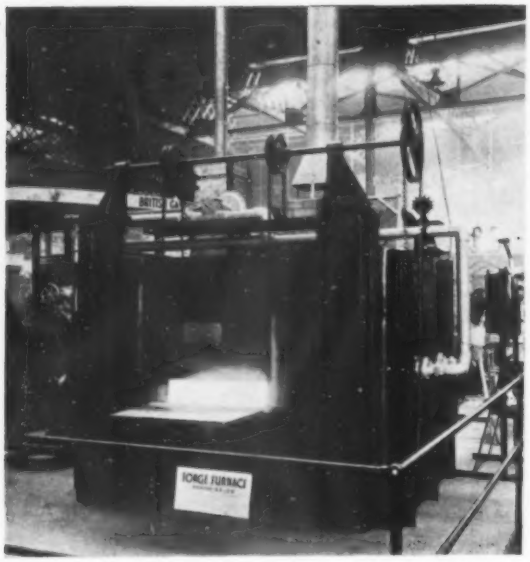
Users of refractories will be interested in the range of materials exhibited by John G. Stein and Co. Ltd. Both standard and special shapes fully maintain the high standard of finish and accuracy of size which are characteristic of their products. Of primary importance in the display is the range of firebricks shown which, varying in composition from 30% to 44% alumina, includes the two brands " Nettle " and " Thistle." For extremely high temperatures or severe corrosion and erosion, the more highly aluminous products are especially suitable, and in this connection " Stein 80 " and " Stein Sillimanite " brands are worthy of attention.

Other brands on view include the standard sizes and special shapes of alumina-silica " Myrtle " and " Bluebell," also " Stein H.T.1.," a heat-insulating brick with a range of application up to a face temperature of 1,350° C., and a sphere of usefulness in reducing heat losses which is receiving increasing recognition. To be seen also is a very useful range of refractory cements and plastic ramming compounds.

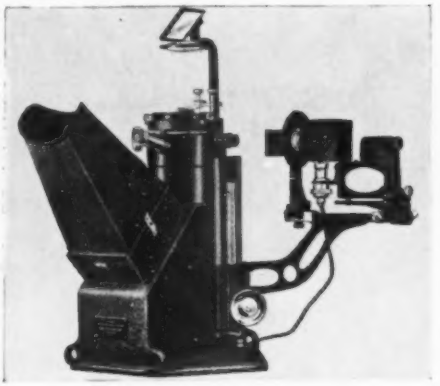
Another interesting exhibit of refractories is displayed by Messrs. Gibbons (Dudley) Ltd., the various types available being sufficiently comprehensive to cover the bulk of industrial requirements. Silica materials are exhibited in the form of bricks, segmented gas retorts and coke-oven shapes, very accurate finish being a noteworthy feature. In addition to refractory insulating brick, various types of fireclay and aluminous materials are exhibited, and also a range of super-refractories in silicon carbide, fused alumina and sillimanite.

Welding and Cutting Machines and Appliances

To-day, in the construction and service of machinery, and in the production of metal products, there is such a wide range of possibilities in which the oxy-acetylene process can save pounds in extending earning profits, lowering bills for replacements and maintenance, that the progressive engineer will find it an advantage to investigate the gains which can be effected. During 1937 the use of the appropriate technique of welding, the right type of plant, and following the correct procedures, has given many manufacturers and engineers benefits which had previously not been realised. Discerning visitors, who are especially interested in the possibilities of gas cutting and welding or in electric welding, will find much of interest and value at the Birmingham section.



Gas-fired forge furnace with automatic air/gas proportioning devices.



Vickers projection microscope exhibited at Olympia by Cooke, Troughton & Simon Ltd.

having special devices to prevent sealing and decarburisation, one embodying a protective gas curtain device, and another by the Sheffield Gas Co., equipped with their inert atmosphere system.

Another interesting feature is the number of furnaces for dealing with the heat-treatment of light alloys, which are of particular interest to the aircraft industry; while there is an imposing array of control equipment from the small direct-expansion thermostat to the more complicated electrical pyrometer control panels for large furnaces. An interesting newcomer is an air-operated time temperature control for ovens by Bristol's Instrument Co.; another is George Kent's new "Multelec" potentiometric controller.

Industrial Gas Exhibit

Town gas is used in so many different ways that it must be difficult to demonstrate the many applications at an exhibition, but the composite exhibit of the British Gas Federation, arranged in conjunction with the makers of gas equipment, is very comprehensive. In addition to the working demonstration of aluminium die-casting and hot-brass stamping previously mentioned, information has come to hand as we go to press regarding further interesting exhibits which should be seen to be fully appreciated.

Of particular interest to the heavy industries is a forge furnace. Built to stand up to the severe conditions of the forge shop, gas and air blast burners are used without recuperators or regenerators, yet the thermal efficiency is relatively high. However, probably the most important individual use of gas in industry is the heat-treatment of metals. For general work up to 1,000° C. a furnace is exhibited by The Incandescent Heat Co. Its heavy insulation and large recuperator give this furnace a low maintenance rate and make it especially suitable for continuous working. Three types of high-speed steel-hardening furnaces are also exhibited, the two larger ones

Gas-fired general furnace for heat-treatment work up to 1,000° C.

Progress in the Aluminium Industry in Switzerland

Continued from page 154.

can has the advantage of preserving its appearance after many years of service.

From the early days of the industry it was recognised that one of the most important duties of the research laboratories was to disseminate the results of research in order that developments could be applied in the various industries with as little delay as possible. Numerous publications in many technical journals and reports before metallurgical and engineering societies have contributed in spreading knowledge regarding these alloys. To supplement this information the Company has given practical demonstrations in workshops and factories, and through its technical staff is ready to render every possible assistance to ensure the proper technique in operations with these alloys.

To-day, aluminium alloys are used by all sections of Swiss engineering industry, and it is doubtful whether there is an enterprise which does not use aluminium alloys. This general introduction of the light alloys, performed during the last 15 years, is eloquent testimony of the co-operation of research, technical and commercial management of the aluminium-producing Company as well as aluminium users. As a result of this co-operation the industries working aluminium last year constituted the Union of Swiss Aluminium Manufacturers ("Verein Schweizerischer Aluminiumindustrieller").

Obituary

Edward G. Herbert, B.Sc., M.I.Mech.E.

Many readers will learn with regret of the death of Mr. E. G. Herbert on the 9th inst., after an illness of three months. Although he was a director of a firm of machine tool makers which bears his name, probably he will be remembered more for his research work and development of hardness testing instruments, while his work on the periodic fluctuations of hardness occurring in metals which have been rotated in a magnetic field will be familiar to many.

Business Notes and News

Vickers Propose Pension Scheme

Vickers Limited announce that for some time past they and the Boards of their subsidiary companies have been giving consideration to the introduction of a pension and life assurance scheme for the members of the staffs. As a result, schemes have been arranged which it is hoped will come into operation on March 1 next. Detailed particulars of the schemes are being put before the members of each company's staff in the course of the next few days.

The eventual adoption of the schemes (as is usual in these cases) is contingent on an agreed percentage of the eligible members electing to join. In future it will be compulsory for all new members of the staffs to enter. The members of the staffs who will be offered participation in the schemes number between 6,000 and 7,000.

Work on the New Mauretania

One of the biggest castings for the new Cunard-White Star liner, *Mauretania*, has recently been completed at the Darlington Forge Company. This company has produced some 200 tons of castings for the liner, including rudder and stock (approximately 90 tons), shaft brackets (45 tons approximately) and the stern frame which weighs in the region of 40 tons. The latter is nearly 100 ft. long, and the castings have been delivered to Cammell Laird's Birkenhead shipyard in sections.

The 35-ft. steel tail-shafts are being completed at the works of the Sheffield Steel Corporation. The shafts are of 2 ft. diameter, lined with brass and each weighs approximately 25 tons. Thirty drums will be fitted in the boilers, and work is now in progress at Birkenhead, drilling 15 of these drums. The 32,000-ton liner will be launched on July 28, which is only 14 months since the laying of her keel plates.

Light Metal Production

It appears likely that the Lancashire Metal Sublimation Corporation Ltd. will acquire a site in Warrington to produce both chemicals and metals, the company envisaging the production of a metal lighter than metal, and of increased strength; such a metal as this would be most valuable in aircraft construction, to name but one application.

All being well, it is anticipated that plant will be installed very soon. The site in prospect is one that was formerly owned by the United Alkali Company, and the land has since been acquired by the St. Helens Corporation.

New Tube Works on the Clyde
Production Shortly

Excellent progress is being made in the erection, on the North Hillington estate between Glasgow and Paisley, of the new factory for Scottish Non-Ferrous Tube Industries Ltd. The formation of this new company, which is a joint undertaking by Coltness Iron Co. Ltd., and Imperial Chemical Industries Ltd., was, it will be remembered, announced by the Commissioner for the Special Areas (Scotland) a few months ago. The works are being built for the manufacture of non-ferrous metal tubes for housing, engineering, and shipbuilding purposes, for both home and export markets, and are planned to be in production shortly. The new company, having the expert technical assistance of both the well-known firms it represents, ensures that this entirely new factory will incorporate the latest developments in machinery, plant layout and manufacturing technique associated with tube production.

Scottish Non-Ferrous Tube Industries Ltd. will manufacture, amongst other things, copper tubes of all types, including those used in naval and mercantile marine construction, for domestic water services, for the conveyance of gas, and for electrical conduit. They will also produce condenser tubes for marine and land station work in cupro-nickel, aluminium brass, Admiralty brass, etc. For this purpose the works will stand in a very favourable geographical position, as Clydeside has a large consumption of all types of condenser tubes.

Electric power for the factory is being supplied by the Clyde Valley Electrical Power Company, and gas and water are being taken from the Glasgow Corporation supply. Local labour is being utilised as far as possible for staffing the factory, and a scheme has been worked out for the training of employees who will be entrusted with jobs requiring special skill.

United Steel Company's Birmingham Office

The Birmingham office was recently moved from the old Martino Steelworks, in Princip Street, to a modern suite of offices in the centre of the city, readily accessible from both New Street and Snow Hill stations. The new address is Union Chambers, Temple Row, Birmingham, and the telephone number is Midland 6321.

Manchukuo Developments

Big developments are foreshadowed in Manchukuo, a plan having been drawn up between the Showa Steel Works and the Manchukuo government for the systematic development of all iron mines in the country, including Anshan, Penhsihu and Tungpientao. The plan aims at a production of five million tons of iron and three million tons of steel after the first few years' developments.

The Showa company began their third-term expansion this year and are also trying to complete a fourth-term expansion within the one year. It is estimated that the Showa present output of 700,000 tons of iron and 500,000 tons of steel will be increased to no less than 1,700,000 tons of iron and 1,000,000 tons of steel when the present expansion is completed.

The formation of a vast iron concern, making a combination of Japanese and Manchukuoan interests has for its object the exploitation of the mineral resources of Manchukuo. The Showa Steel Works and the Penhshihu Iron Company will then be merged in the new company.

Progress at Jarrow

Work is progressing satisfactorily at the new works, opened at Palmer's boiler shop, which were put into operation a few weeks ago when the first melting furnace was started. There are a large number of orders on hand, and in about another month a further furnace will be installed, and a third about a month later. At present about 250 men are employed at the works, and it is stated that everything is working to schedule.

Good progress is also being made with the erection of plant at the new tube works, and it is expected that manufacturing operations will start at an early date.

Central German Steel Developments

The first of four great steel works is expected to be ready in the Bleckenstedt district of Lower Saxony towards the end of the year, and the estimated capacity of the four works has been placed at 1,000,000 tons of raw steel per year.

A group of eight blast furnaces, with coke ovens, rolling mills and auxiliary plant, will be erected. Completion of these works will probably mean that approximately 15,000,000 tons of ore will be needed each year, and these will be drawn from the Salzgitter district, whose annual surplus would then be 6,000,000 tons, which surplus would be drafted to act as reserves in the Ruhr. The Salzgitter ore is stated to contain 25 to 40% iron.

There are also large deposits of ore in the region between the Midland Canal and the North Hartz, and another large field is believed to exist north of the Midland Canal, this containing limestone ore. Although the extent of the ore fields is estimated at thousands of millions of tons, there are considerable difficulties in surveying as shafts have to be sunk, in places, to a depth of 3,000 ft. before samples can be obtained.

The Lincoln Arc Welding Foundation

When the open competition organised by the James F. Lincoln Arc Welding Foundation was first announced, it was thought that few entries would be received from this country because of the intense industrial activity prevailing, which left little time for developing new processes and studying the application of the electric arc. There has, however, been a ready response and in order to further the work of the Foundation and to deal with the increasing volume of inquiries, a London office has been opened with a British secretary.

The Foundation has been endowed with a Trust Fund empowered to distribute £40,000 as prizes for papers to be submitted on welding subjects. Anyone can enter and papers are treated as confidential, and will not be published, except with the author's consent. Information on the many classifications under which papers may be submitted can be obtained from the secretary, The James F. Lincoln Arc Welding Foundation, British Office, Thames House, Millbank, London, S.W. 1.

MARKET PRICES

ALUMINIUM.

98/99% Purity		£100	0	0

ANTIMONY.

English		£81	10	0
Chinese		67	0	0
Crude		39	0	0

BRASS.

Solid Drawn Tubes	lb.	0	0	11¼
Brazed Tubes	,,	0	1	1¼
Rods Drawn	,,	0	0	9
Wire	,,	0	0	8¼
*Extruded Brass Bars	,,	0	0	5⅛

COPPER.

Standard Cash		£39	0	0
Electrolytic		39	5	6
Best Selected		42	11	0
Tough		42	1	0
Sheets		75	16	6
Wire Bars		43	16	0
Ingot Bars		43	16	0
Solid Drawn Tubes	lb.	0	1	0¾
Brazed Tubes	,,	0	1	0½

FERRO ALLOYS.

‡Tungsten Metal ° Powder. nominal	lb.	£0	6	1½
‡Ferro Tungsten ° nominal	,,	0	6	0
Ferro Molybdenum °				
Ferro Chrome, 60-70% Chr. Basis 60% Chr. 2-ton lots or up.				
NOMINAL 2–4% Carbon, scale 12/– per unit	ton	34	15	0
NOMINAL 4–6% Carbon, scale 8/– per unit	,,	24	5	0
NOMINAL 6–8% Carbon, scale 7/6 per unit	,,	24	0	0
NOMINAL 8–10% Carbon, scale 7/6 per unit	,,	24	0	0
§Ferro Chrome, Specially Refined, broken in small pieces for Crucible Steelwork. Quantities of 1 ton or over. Basis 60% Ch. Guar. max. 2% Carbon, scale 12/6 per unit	,,	37	0	0
Guar. max. 1% Carbon. scale 13/– per unit	,,	39	0	0
§Guar. max. 0.5% Carbon, scale 13/– per unit	,,	49	0	0
‡Manganese Metal 97–98% Mn	lb.	0	1	3
‡Metallic Chromium	,,	0	2	5
§Ferro-Vanadium 25–50%	,,	0	14	0
§Spiegel, 18–20%	ton	11	0	0
Ferro Silicon—				
Basis 10%, scale 3/– per unit nominal	ton	10	5	0
20/30% basis 25%, scale 3/6 per unit	,,	12	0	0
45/50% basis 45%, scale 5/– per unit	,,	12	10	0
70/80% basis 75%, scale 7/– per unit	,,	17	0	0
90/95% basis 90%, scale 10/– per unit	,,	30	0	0
§Silico Manganese 65/75% Mn., basis 65% Mn.	,,	18	15	0
§Ferro - Carbon Titanium, 15/18% Ti	lb.	0	0	4½
Ferro Phosphorus, 20–25%	ton	22	0	0
§Ferro-Molybdenum, Molyte	lb.	0	4	9
§Calcium Molybdate	,,	0	4	5

FUELS.

Foundry Coke—				
S. Wales	—	2	2	6
Scotland	—	2	2	6
Durham	—	1	19	6
Furnace Coke—				
Scotland	—	2	0	0
S. Wales	—	1	17	6
Durham	1 12 6 to	1	17	6

GUN METAL.

*Admiralty Gunmetal Ingots (88 : 10 : 2)		£68	0	0
*Commercial Ingots		51	0	0
*Gunmetal Bars, Tank brand, 1 in. dia. and upwards	lb.	0	0	11
*Cored Bars	,,	0	1	1

MANUFACTURED IRON.

Scotland—				
Crown Bars,		£13	10	0
N.E. Coast—				
Rivets		12	15	0
Best Bars		15	15	0
Common Bars		12	10	0
Lancashire—				
Crown Bars		13	10	0
Hoops		14	2	6
Midlands—				
Crown Bars		13	10	0
Marked Bars		15	15	0
Unmarked Bars			—	
Nut and Bolt Bars		11	15	0
Gas Strip		14	2	6
S. Yorks.—				
Best Bars		15	15	0
Hoops		14	2	6

PHOSPHOR BRONZE.

*Bars, "Tank" brand, 1 in. dia. and upwards—Solid	lb.	£0	0	11
*Cored Bars	,,	0	1	1
†Strip	,,	0	0	10¾
†Sheet to 10 W.G.	,,	0	0	11¼
†Wire	,,	0	1	0¾
†Rods	,,	0	1	0½
†Tubes	,,	0	1	6½
†Castings	,,	0	1	3½

†10% Phos. Cop. £33 above B.S.
†15% Phos. Cop. £38 above B.S.
†Phos. Tin (5%) £32 above English Ingots.

PIG IRON.

Scotland—			
Hæmatite M/Nos.	£6	13	0
Foundry No. 1	6	0	6
,, No. 3	5	18	0
N.E. Coast—			
Hæmatite No. 1	6	13	0
Foundry No. 1	5	11	6
,, No. 3	5	9	0
,, No. 4	5	8	0
Silicon Iron		—	
Forge	5	8	0
Midlands—			
N. Staffs. Forge No. 4	5	8	0
,, Foundry No. 3	5	11	0
Northants—			
Foundry No. 1	5	11	6
Forge No. 4	5	5	6
Foundry No. 3	5	8	6
Derbyshire Forge	5	10	0
,, Foundry No. 1	5	14	0
,, Foundry No. 3	5	11	0
West Coast Hæmatite	7	4	8
East ,, ,,	7	3	6

SWEDISH CHARCOAL IRON AND STEEL.

Export pig-iron, maximum percentage of sulphur 0·015, of phosphorus 0·025.
Per English ton Kr.190

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Per metric ton Kr.335-385
Per English ton .. £17 11 3/£20 3 9

Wire Rods, over 0·45 Carbon.
Per metric ton Kr.385-415
Per English ton .. £20 3 9/£21 15 0

Rolled Martin Iron, basis price.
Per metric ton Kr.290-310
Per English ton .. £15 4 0/£16 5 0

Rolled charcoal iron, finished bars, basis price.
Per metric ton Kr.360
Per English ton £18 17 6
f.o.b. Gothenburg.

SCRAP METAL.

Copper, Clean	£32	0	0
,, Brazery	29	0	0
,, Wire		—	
Brass	22	10	0
Gun Metal	32	0	0
Zinc	8	0	0
Aluminium Cuttings	71	0	0
Lead	13	10	0
Heavy Steel—			
S. Wales	3	10	0
Scotland	3	6	0
Cleveland	3	7	0
Cast Iron—			
Midlands	3	5	0
S. Wales	3	10	0
Cleveland	4	2	6
Steel Turnings—			
Cleveland	2	12	6
Midlands	2	5	0
Cast Iron Borings—			
Cleveland		—	
Scotland	2	2	6

SPELTER.

G.O.B. Official		—	
Hard	£11	10	0
English	15	2	6
India	13	10	0
Re-melted	12	0	0

STEEL.

Ship, Bridge, and Tank Plates.			
Scotland	£11	10	0
North-East Coast	11	10	0
Midlands	11	10	0
Boiler Plates (Land) Scotland	12	0	0
,, ,, (Marine) ,,		—	
,, ,, (Land), N.E.Coast	12	0	0
,, ,, (Marine) ,,		—	
Angles, Scotland	11	0	6
,, North-East Coast	11	0	6
,, Midlands	11	0	6
Joists	11	6	0
Heavy Rails	10	2	6
Fishplates	14	2	6
Light Rails	10	7	6
Sheffield—			
Siemens Acid Billets	11	15	0
Hard Basic .. £6 17 6 to	10	2	6
Medium Basic, £6 12 6 and	10	0	0
Soft Basic	8	15	0
Hoops	11	15	0
Manchester			
Hoops	11	5	0
Scotland, Sheets 24 B.G.	15	15	0

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Finished Bars 14% Tungsten	lb.	£0	3	6
Finished Bars 18% Tungsten	,,	0	4	6
Extras :				
Round and Squares, ½ in. to ¼ in.	,,	0	0	3
Under ¼ in. to ⅛ in.	,,	0	1	0
Round and Squares, 3 in.	,,	0	0	4
Flats under 1 in. × ⅜ in.	,,	0	0	3
,, ,, ½ in. × ¼ in.	,,	0	1	0

TIN.

Standard Cash	£181	15	0
English	181	15	0
Australian		—	
Eastern	184	7	6
Tin Plates I.C. 20 × 14 box	1	2	6

ZINC.

English Sheets	£28	10	0
Rods	28	10	0
Battery Plates		—	
Boiler Plates		—	

LEAD.

Soft Foreign	£15	5	0
English	17	5	0

* McKechnie Brothers, Ltd., Feb. 11. † C. Clifford & Son, Ltd., Feb. 11. ‡ Murex Limited, Feb. 11.
Subject to Market fluctuations. Buyers are advised to send inquiries for current prices when about to place order.
Jan./Mar. 1938 § Prices ex warehouse, Feb. 11. ¶ The prices fluctuate with the price of Tungsten.

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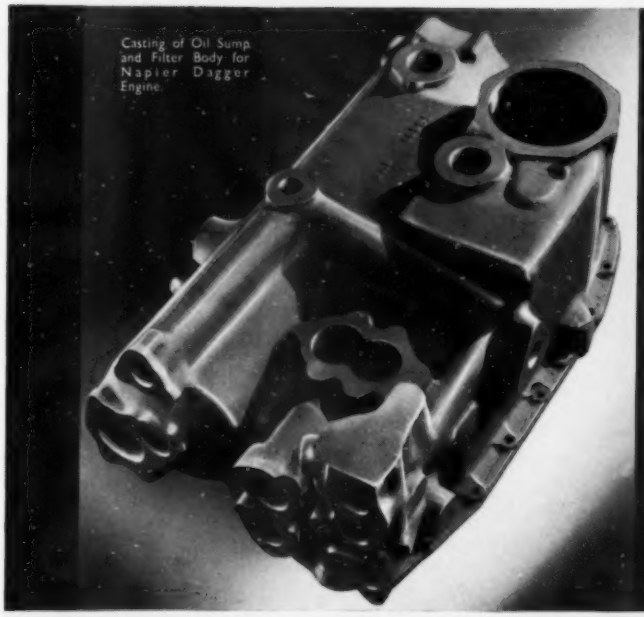

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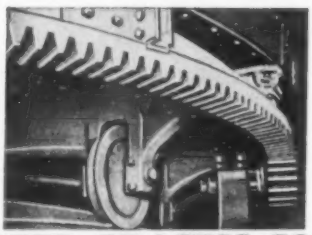

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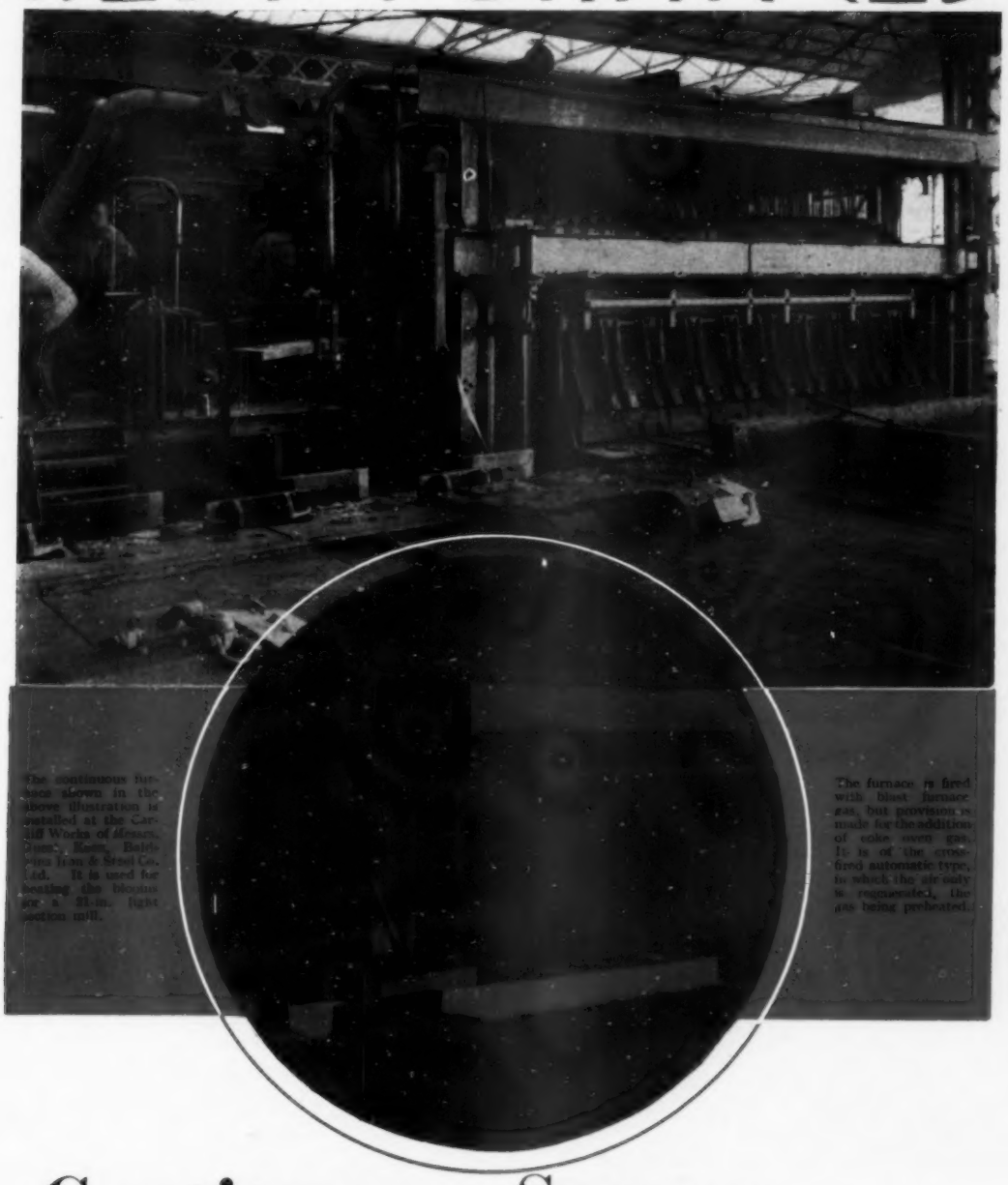

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